# The Role of Categorical Information in Refutation Texts

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In two experiments we investigated the hypotheses that a) the refutation of more than one alternative conception, and b) the inclusion of categorical information in a refutation text will facilitate elementary school children's understanding of the scientific concept of the Earth. The results of the first experiment showed no clear support of the first hypothesis but suggested that the inclusion of categorical information - information about the ontological category in which a concept belongs - is more effective than other kinds of information. The second experiment controlled for the amount of information and compared only the inclusion of categorical vs. non-categorical information in refutation and non-refutation texts. The results showed that the texts that included the categorical information improved children's understanding of the scientific information more than all the other texts. This result needs to be replicated using more examples from other science domains.

**Keywords:** *text comprehension, refutation text, conceptual change, ontological category change*

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## 1. Introduction

Students, and especially elementary school children, have considerable difficulties in understanding the scientific information presented in science texts (Goldman & Bisanz, 2002; Graesser, Leon, & Otero, 2002). One possible reason for this difficulty is that science texts do not usually take into consideration students' incompatible prior knowledge and alternative conceptions (Mikkila-Erdmann, 2002). On the contrary, they seem to assume that the readers already have prior knowledge sufficient enough to understand the new information given in the text (O'Reilly & McNamara, 2007).

The comprehension of an expository text that presents scientific information often requires considerable conceptual changes to happen in readers' background knowledge. Research has shown that even preschool children who have not been exposed to science have nevertheless constructed naïve beliefs and theories, which are based on their everyday experience, and which are very different from the scientific explanations found in science texts. When expository texts present counter-intuitive scientific information which may not be supported by the readers background knowledge, the use of refutation texts – i.e., texts that acknowledge students' alternative conceptions and then explicitly refute them- has been found to produce better results than non-refutation texts (Broughton & Sinatra, 2010; Diakidoy, Kendeou, & Ioannides, 2002; Dole, 2000; Guzzetti, Williams, Skeels, & Wu, 1997). Refutation texts are more effective than non-refutation texts in promoting the understanding of scientific information in a variety of science domains, such as energy (Diakidoy, Kendeou, & Ioannides, 2003), mechanics (Guzzetti et al., 1997; Hynd, McWhorter, Phares, & Suttles, 1994), photosynthesis (Mikkila-Erdmann, 2002), and light (Mason, Gava, & Boldrin, 2008).

The effectiveness of refutation texts has been explained on the grounds that they create cognitive conflict in the students who read them because they explicitly acknowledge readers' alternative conceptions and contrast them to the incompatible scientific information (Guzzetti, Snyder, Glass, & Gamas, 1993). When reading a refutation text students are more likely to become aware of the incompatibility between their alternative conceptions and the scientific explanations and therefore are more likely to engage in the conceptual change processes required to inhibit inappropriate prior knowledge and understand the scientific information, compared to a situation where no refutation is used. Research investigating how readers process refutation text using both on-line (think-aloud reading times) and off-line (recall) measures (e.g., Kendeou and van den Broek, 2005, 2007) showed that students with alternative conceptions engaged in different processes when reading a refutation text describing Newton's laws, suggesting that these readers were becoming aware of the conflict between their prior knowledge and the text information.

Refutation text studies usually include the use of two texts: A non-refutation, text, and a refutation one. The refutation text presents a common alternative conception, usually stated in one sentence, refutes it in the sentence that follows and then gives the scientific explanation. The non-refutation text presents only the scientific explanation on the issue (Tippett, 2010). Refutation research has focused mainly on the influence of the text format (refutation vs. non-refutation) on students' understanding of the scientific information and has not investigated whether other variables, such as the *amount of relevant information* and the *kind of information* refuted may also play a role. The present research investigates the hypotheses that the amount and type of information refuted may influence students understanding when reading a text explaining the scientific concept of the Earth.

With respect to the amount of information refuted, it is argued that the refutation of two or even more alternative conceptions might be more effective than the refutation of only one. This is the case because students often have a number of alternative conceptions that can prevent them from understanding a scientific explanation. For example, research have shown that students' understanding of the scientific concept of the Earth is difficult for elementary students to understand because they cannot reconcile the spherical shape of the Earth with their everyday experience of a flat ground, and also because they believe that people would fall off from the sides and bottom of a spherical Earth (Nussbaum, 1985; Nussbaum & Novak, 1979; Sneider & Pulos, 1983; Vosniadou & Brewer, 1992). In other words, there are two, not one alternative conceptions– i.e., the flatness and up/down gravity – that can stand in the way of young children's understanding the spherical shape of the earth.

Hayes, Goodhew, Heit, and Gillan (2003) investigated whether the amount of relevant information could promote change in children's ideas about the Earth in a non-refutation text study. Non-refutation texts and videos were used to explain how it is possible for the Earth to be round when it appears to be flat and how it is possible for people to live on the spherical Earth without falling off it. In one condition the participants received instruction that explained both of the above-mentioned alternative conceptions, while in other conditions they received instruction that explained only one of them. The results showed that the children who received instruction referring to both of the above-mentioned alternative conceptions were more likely to fully understand the spherical shape of the Earth compared to the children in the other conditions. The findings support the hypothesis that the understanding of scientific information will be facilitated when diverse aspects of children's alternative conceptions are challenged. The purpose of the present study is to investigate this hypothesis using refutation text.

With respect to the question regarding the kind of information refuted, we argue that the refutation of categorical information, i.e., information that explicitly states the category to which a concept belongs, may be more effective than other types of information. Categorization is one of the most powerful learning mechanisms. When a new object is assigned to a given category, all the characteristics of the category are transferred to this object (Chi, 2013; Medin & Rips, 2005). During development and as students are exposed to science instruction many concepts are re-assigned to new categories. This re-categorization is an important part of the conceptual change processes that takes place in the learning science (Carey, 1985, 2009; Chi, 2013; Vosniadou, 2013). When a concept is re-categorized, new characteristics are assigned to it, those applied to the members of the new category. Many of the alternative conceptions that children form, happen because they assign concepts to the wrong ontological category. When conceptual change is achieved, a new scientific concept has been formed which has either been re-assigned to a different existing category, or to an altogether new category In many cases, as for example in the case of concepts like *heat, energy, force, and matter*, the new, scientific category does not exist and needs to be constructed with the help of specific instruction (Chi, 2013).

The concept of the Earth is one of the concepts that undergo changes in categorization with the learning of science. Research has shown that children have considerable difficulty understanding that the Earth is a sphere that rotates around its axis and revolves around the Sun (Vosniadou & Brewer, 1992, 1994). It has been argued that this is the case because children categorize the Earth not as an astronomical object, but as a physical object and apply to it the characteristics of physical objects. These in turn constrain children's understanding of the scientific information about the Earth and become the cause for the formation of various kinds of misrepresentations of the earth. Vosniadou & Skopeliti (2005) examined in detail this hypothesis and showed that there is a shift in children's categorizations of the Earth from a physical object to an astronomical object, and that this shift is related to children's understanding of the scientific model of the Earth. In this study 62 1st and 5th grade children were shown 10 cards with the words 'SUN', 'MOON', 'STAR', 'EARTH', 'PLANET', 'HOUSE', 'CAT', 'ROCK', 'TREE', and 'CAR' and were asked to place them in the categories in which they best belong. The results showed that the great majority of the children were able to distinguish physical from astronomical objects and that there was a developmental shift in their categorizations of the Earth. Many of the younger children thought that the Earth belongs with the physical objects, while practically all of the 5th graders categorized the Earth with the astronomical objects. Furthermore, significant correlations were obtained between children's categorizations and their Earth shape models.

To summarize, existing research suggests that the comprehension of scientific information is facilitated when the diversity of students' existing alternative conceptions are addressed. Prior research also shows that the learning of science often requires considerable changes in students' initial categorizations and that the assignment of a concept to the wrong ontological category is an important source of difficulty in learning science. Based on the above, it was hypothesized that a) the refutation of more than one relevant alternative conception, and b) the inclusion of categorical information in a refutation text might facilitate the understanding of a scientific concept more compared to refutation texts that refuted only one alternative conception. The purpose of the present research was to investigate these two hypotheses using texts that introduced the scientific concept of the Earth.

## 2. Experiment 1

The first experiment tested the hypotheses that both the *amount* and the *kind* of information included in a refutation text will influence students' understanding of the scientific concept of the Earth. Three refutation texts on the topic of the Earth were constructed and compared. The first refuted the belief that the Earth is flat (Text 1) while the second refuted both the belief that the Earth is flat and also the belief that people cannot live at the bottom of the Earth because they will fall down (Text 2). The third text contained, in addition to the two beliefs already mentioned, the categorical information that the Earth is an astronomical object, i.e., a spherical planet in a heliocentric solar system, and not a physical object (Text 3).

It was hypothesized that all refutation texts would improve children's responses in the posttest, based on previous research showing that when children's alternative conceptions are taken into consideration and are explicitly refuted, text comprehension is improved (Mikkilä-Erdmann, 2002; O'Reilly & McNamara, 2007). Second, it was hypothesized that Texts 2 and 3 would be more effective compared to Text 1 because they deal with a diversity of children's alternative conceptions. Third, it was hypothesized that Text 3, which included the categorical information that the Earth is an astronomical object, would improve children's understanding of the scientific information more compared to the other two refutation texts. This is the case because categorical information is generic and allows children to see the Earth as similar to other astronomical objects in space. If the children conceptualize the Earth as an astronomical object, they will avoid applying to it characteristics of physical objects, such as stability, need of support, and up/down gravity, thus minimizing the risk of creating alternative conceptions, such as that the Earth is a hollow sphere or a flat disc (Vosniadou & Brewer, 1992).

## 2.1 Method

### *2.1.1 Participants*

Eighty-one 3rd grade students from three different classrooms participated in the study. Their age ranged from 8 years and 1 month to 8 years and 11 months (mean age 8 years and 4 months). Third graders were selected because previous studies have shown that although they are exposed to scientific information about the Earth they do not yet fully understand it (Nussbaum, 1985; Sneider & Pulos, 1983; Vosniadou & Brewer, 1992). Furthermore, this is the youngest age at which we expect children to be able to read and understand a simple science text.

### *2.1.2 Materials*

Three different refutation texts were constructed which referred to the Earth. A translation of these Texts is shown in Table 1. Text 1 refuted the belief that the Earth is flat and explained that it is spherical. It included paragraphs 1, 3, & 4 from Table 1 (310 words). Text 2 included all the information found in Text 1 and also added paragraph 5, which refuted the belief that people can fall off the Earth, and explained that there is force called gravity that holds people on to the surface of the spherical Earth (410 words). Text 3 included all the information found in Texts 1 and 2 and also added paragraph 2, which included the information that the Earth is an astronomical object (510 words). All texts were of comparable readability level, appropriate for third graders, according to the Flesch-Kincaid Grade Level Scale.[1]

A questionnaire was constructed and used as a pre-test and as a post-test for all conditions (Table 2). The questionnaire was divided in two groups of questions: *Explicit* and *Inferential*. The explicit questions were questions the answer to which could be obtained directly from the texts. The inferential questions were questions the answers to which were not

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[1] The Flesch-Kincaid Grade Level Scale index for 3rd graders is from 90 to 100. The Flesch index was 95.84 for Text 1, 91.32 for text 2, and 93.24 for Text 3.

**Table 1.** Translation of the Refutation Texts Used in Experiment 1

**The Shape of the Earth: Spherical - *Not* Flat**

1. From ancient years people were wondering "What is the shape of the Earth?". At that time people thought that the Earth is flat, like a very big flat surface, because it appears that way. The Babylonians thought that the Earth is like a very large disk, a very big pancake, which floats on the sea. Also, Homer described the Earth like a very large disk. Today, we know that the Earth is not flat but spherical, like a very big ball.

2. We also know that the Earth is an astronomical object. The universe has many astronomical objects, like stars, planets, comets, etc. The Earth is one of the planets of our solar system. Today we know that our solar system is heliocentric. All the planets are revolving around the sun, which is located in the middle of the solar system. The Earth is also a planet with all the characteristics of planets. All planets are spherical, and round like very large balls.

3. The idea that the Earth is round like a very big ball appears in the 5th century BC. The first person who supported this idea was Pythagoras and later Aristotle. This idea was confirmed in the 16th century AC after Magellan's journey around the Earth. Magellan departed from Spain in 1519 and in 1522 returned to Spain after he traveled around the Earth. Magellan's ship was the first ship which actually went around the Earth. His trip demonstrated that the Earth is round like a very big ball.

4. Someone might ask "How is it possible that the Earth is round like a ball when it seems to us to be flat?". Let us have a look at the globe which shows us how the Earth really is. When we see the whole Earth, as we would have seen if we were on the moon, the Earth looks like a big, spherical ball. However, to us who live on the Earth, on a small part of it, the Earth looks flat. We cannot see the whole Earth, we can only see a small part, which appears to be flat when we are on the Earth. Thus, while the Earth is a big round ball, it seems flat to us because we live only on a small part of it.

5. Another question is "How can people live on a big round ball, and especially at the bottom of it, without falling down?". Today we know that what holds us on the surface of the Earth and we do not fall down from it is the force of gravity. Gravity pulls everything on the Earth's surface towards the centre of the Earth. Thus, it prevents them from falling off from the Earth into space. Because of the force of gravity people can live on different parts all around the of the surface of the spherical Earth without falling off.

explicitly stated in the texts but could be inferred from them (Questions 6 to 12).

**Table 2.** Trnaslation of the Questionnarie Used in Experiment 1

1. To which one of the two groups below does the “Earth” best belong?
   Group 1: tree, rock, house, car / Group 2: planet, star, moon, sun
2. Why do you think the “Earth” belongs better with this group? (mention the group the child has selected)
3. Draw the shape of the Earth as you think it really is.
4. Now in the same drawing, draw some people, wherever you think people really live.
5. In the same picture, draw the sky, wherever you think the sky really is.
6. If you walked for many days in a straight line, where would you end up? ...............
7. Is there an end or an edge to the Earth? Would you ever reach the end/edge of the Earth? ...........................................................................................................
8. (If yes) Would you fall off that end/edge? ...................................................................
9. Why? / Why not? ...........................................................................................................
10. Draw the Earth together with the sun and the moon, as you think they really are.
11. Which one do you think is bigger, the Earth, the sun or the moon? .........................
12. Which one do you think is smaller, the Earth, the sun, or the moon? .....................
13. From the pictures that follow mark the one that you think represents the Earth best and write why you chose that picture..........................................................................

14. Here is the picture [illegible] s house is on the Earth, isn’t it? How come here the Earth is flat but before you draw it round? .......................................................

### *2.1.3 Procedure*

The children in each of the three classrooms were randomly assigned to one of the three experimental conditions. The pre-test was administered first. When all children finished answering the pretest, the answer sheets were collected and a written copy of one of the refutation texts was distributed.

The children had 15 minutes to read the text on their own. At the end of the reading period, the experimenter read the text aloud in order to make sure that the children could decode all the words. Then the refutation texts were removed and the posttest was administered.

### *2.1.4 Scoring*

Two independent judges agreed on a scoring key and used it to score children's responses independently. Agreement was calculated at 95% [*Kendall's tau* $\tau=0.939$; $N=81$; $p<.001$]. All disagreements were discussed until a common score had been achieved on all the items. Children's responses to each of the 14 questions received a score of 1 if they were 'initial' and showed no exposure to scientific information (e.g., if they said that the Earth is flat). Responses that revealed an alternative conception that showed exposure to scientific information that was not fully understood received a score of 2; for example, if the children drew the Earth as a hollow sphere, or if they categorized the Earth both with the astronomical and the physical objects. All the scientific responses received a score of 3. Finally, if the children said they did not know the answer and gave no response, they were marked as 0. Thus, for each student the total score could range from 0 to 42.

## **2.2 Results and Discussion**

A one-way analysis of variance with text type as a between subject factor (Text1*Text2*Text3) was conducted on children's performance in the pretest. The results showed no statistically significant differences between the three experimental groups at the time of the pretest [$F(1,78)=.710$, *n.s.*; $\eta^2=.004$]. Subsequently, children's total scores in all the questions of the questionnaire in the pretest and posttest were subjected to a repeated measures analysis of variance with text type as a between subjects variable and pre-post test performance as a within subjects variable. The results showed a main effect for pretest-posttest performance, due to the fact that all refutation texts improved children's responses in the posttest [$F(1,78)=49.742$, $p<.001$; $\eta^2=.389$]. This finding supports the

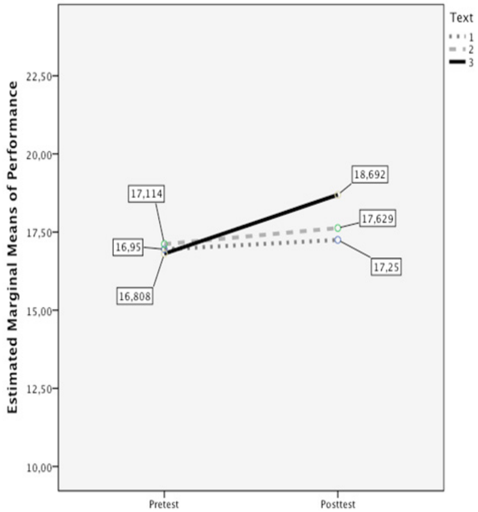


**Figure 1.** Children's Performance as a Function of Text Type

first hypothesis and adds to previous research showing that the use of a refutation text can facilitate children's understanding of a scientific concept (Diakidoy, Kendeou, & Ioannides, 2003; Dole, 2000; Guzzetti, et al., 1997; Hynd, 2001).

The results also showed a statistically significant interaction between text type and pretest-posttest performance [$F(2,78)=15.030$, $p<.001$; $\eta^2=.278$]. As can be seen in Figure 1, the students who read Text 3 showed greater improvement in their responses in the posttest compared to the pretest, as opposed to the students who read Text 1 and Text 2.

Post hoc comparisons using the LSD test indicated that the mean difference in performance from pretest to posttest for Text 3 was statistically significant only when Text 3 was compared to Text 1. The mean difference between Text 2 and Text 3 was in the expected direction but not statistically significant (see Table 3). The mean difference between Text 1 and Text 2 was not statistically different either. Taken together, these results indicate that Text 3 improved children's responses in the posttest more but the difference was statistically significant only compared to Text 1. Since Text 3 refuted more alternative conceptions but also included the categorical

**Table 3.** Mean Difference between Pretest and Posttest Performance in Children's Responses Children's Performance as a Function of Text Type

| Texts | | Mean Difference | Std. Error | Significance |
|---|---|---|---|---|
| 1 | 2 | -0.2714 | .540 | n.s. |
| | 3 | **-0.6500*** | **.573** | **p<.05** |
| 2 | 1 | 0.2714 | .540 | n.s. |
| | 3 | -0.3786 | .499 | n.s. |
| 3 | 1 | **0.6500*** | **.573** | **p<.05** |
| | 2 | 0.3786 | .499 | n.s. |

information that the Earth is an astronomical object, it is not clear which of the two variables made the difference.

In order to investigate hypotheses 2 and 3 further, we analyzed children's performance only in the inferential questions of the questionnaire (questions 6 to 11). A repeated measures analysis of variance with text type as a between subjects variable and pre-post test performance as a within subjects variable showed a main effect for pretest-posttest performance [$F(1,78)=9.503; p<.005; \eta^2=0.109$], and a statistically significant interaction between text type and pretest and posttest performance [$F(2,78)=6.979; p<.005; \eta^2=.152$] (Figure 2).

Post-hoc analysis using the LSD test showed that the difference in performance between the pretest and the posttest was in favor of Text 3 compared to the other two texts (Table 4). Text 3, which included the categorical information, improved children's responses in the inferential questions more than Text 1 and Text 2. The mean difference between Text 1 and Text 2 was not significant.

The above findings provide some support to the hypothesis that it is not the amount of information, but the kind of information, and more specifically, the inclusion of categorical information that facilitated children's understanding of the scientific information. However, a limitation of the present study was that it confounded the amount of information refuted in the texts with the kind of information refuted. Text 3, which was found to be more effective than the other two texts, included the categorical information but also refuted more information than Text 1 and Text 2. In

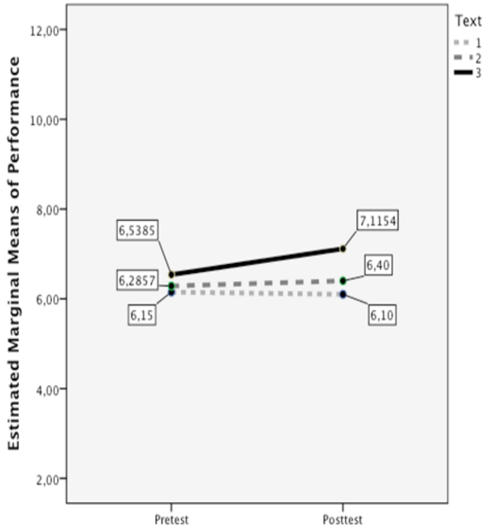


**Figure 2.** Children's Performance in the Inferential Questions as a Function of Text Type

order to test the hypothesis that the inclusion of categorical information in refutation texts facilitates the understanding of scientific information more than other kinds of information, we designed an experiment that controlled for the amount of information refuted and manipulated only the presence of categorical vs. non-categorical information.

**Table 4.** Mean Difference between Pretest and Posttest Performance in Children's Responses to the Inferential Questions

| Texts | | Mean Difference | Std. Error | Significance |
|---|---|---|---|---|
| 1 | 2 | -.2179 | .22952 | n.s. |
| | 3 | **-.7019*** | **.24353** | **p<.05** |
| 2 | 1 | .2179 | .22952 | n.s. |
| | 3 | **-.4841*** | **.21199** | **p<.05** |
| 3 | 1 | **.7019*** | **.24353** | **p<.005** |
| | 2 | **.4841*** | **.21199** | **p<.05** |

## 3. Experiment 2

Experiment 2 tested the hypothesis that it is more important to refute categorical information than non-categorical information in a refutation text. The texts used introduced again the scientific concept of the Earth. The rationale regarding the importance of categorical information is that categorical information is generic and carries with it a great deal of implicit information that can be used by the reader to guide new learning (Chi, 2013; Vosniadou & Skopeliti, 2014). When a concept is categorized in the scientific category to which it belongs, the readers are likely to avoid applying erroneous characteristics to the concept. On the contrary, they are motivated to apply the correct characteristics, thus avoiding the creation of alternative conceptions. With respect to the concept of the Earth, as we argued before, in order for children to understand the scientific concept of the spherical Earth they have to re-categorize it from a physical to an astronomical object. When the category 'astronomical object' appears explicitly in the text and the category 'physical object' is refuted, children are encouraged to represent the Earth as an astronomical object in space and apply to it the corresponding characteristics of other astronomical objects (spherical shape, no need of support, no up/down gravity, etc.). They are encouraged to conceptualize the Earth not from an egocentric perspective -from the perspective of someone being located on the Earth- but from the perspective of someone looking at the Earth from far away, somewhere in space. This information can help children transfer the properties of astronomical objects, like the sun, moon, and other planets to the Earth, avoiding the creation of alternative conceptions. Common alternative conceptions of the Earth, such as that it is round but flat like a pancake, or that people cannot live at the bottom of the Earth, are strongly related with an egocentric representation of the Earth as a physical object, distinct from the astronomical objects that are located above it.

In order to test the categorical information hypothesis, a categorical and a non-categorical refutation text were constructed. In the categorical refutation text, it was stated explicitly that the Earth is an 'astronomical' and not a 'physical' object, having the characteristics of other astronomical objects, namely that it is spherical, that it rotates around itself, and it revolves around the sun. The non-categorical text refuted instead the belief that the Earth is flat. It was stated that the Earth may appear to be flat but that it is not, that it is actually a very large round ball, and that it only looks flat because we live on it and we see its surface from very close.

It might be argued that the presence of the scientific categorical information is important in a science text even when the non-scientific category is not refuted. In order to test the importance of the refutation/non-refutation variable, we also included two non-refutation texts in the experiment. One of them contained the categorical information and the other did not. Thus, the design of the study included two independent variables: categorical vs. non-categorical information, and refutation vs. non-refutation format.

It was hypothesized that the categorical information would be more effective compared to the non-categorical information (Hypothesis 1). It was also hypothesized that the categorical refutation text would facilitate the understanding of the scientific information more than the categorical non-refutation text (Hypothesis 2). An interesting question was whether the categorical non-refutation text would be more effective than the non-categorical refutation text. If that were the case, as we hypothesized that it might be, then the inclusion of categorical information would be shown to be more effective than text format – i.e., refutation vs. non-refutation (Hypothesis 3).

## 3.1 Method

### *3.1.1 Participants*

The participants were 84 3rd grade students from four different classrooms, ranging in age from 8 years and 5 months to 9 years and 2 months (mean age 8 years and 10 months).

### *3.1.2 Materials*

The materials used were: (a) four different texts which referred to the Earth, and (b) a questionnaire consisting of 11 open-ended questions. A translation

**Table 5.** Translation of the Texts Used in Experiment 2

| **The Texts with Categorical Information** | **The Texts without categorical Information** |
|---|---|
| The Earth is an astronomical object like the sun, the moon, the stars, and the planets. **In ancient years people believed that the Earth is a big, stable physical object located in the center of the universe. They also believed that the sun, the moon and all the astronomical objects were located above it. Today we know that the Earth is an astronomical object.**<br><br>The universe has many astronomical objects. The Earth is one of the planets of our solar system and has the characteristics of all the other planets we know. All planets are spherical, round like very large balls, and they rotate around their axis. Many of them have satellites that revolve around them, like for example the moon, which revolves around the Earth.<br><br>The Earth is one of the 9 planets of our solar system. Our solar system consists of the sun, which is located in the middle, and the planets, which revolve around the sun. All the planets of the solar system rotate around their axis and revolve around the sun. In a picture of our solar system we can see the sun and the 9 planets revolving around the sun. One of these planets is the Earth with the moon, which revolves around the Earth. | The Earth is spherical, round like a very big ball. **In ancient years people thought that the Earth is flat, like a very big flat surface, because it appears that way. Others described the Earth like a very large disk, surrounded by mountains. Today we know that the Earth is round like a very big ball.**<br><br>Many years ago, in 1519 Magellan departed from Spain and in 1522 returned to Spain after he traveled around the Earth. Magellan's ship was the first ship which actually went around the Earth. His trip demonstrated that the Earth is round like a very big ball.<br><br>Someone might ask "How is it possible that the Earth is round like a ball when it seems to us to be flat?". Let us have a look at the globe which shows us how the Earth really is. When we see the whole Earth, as we would have seen if we were on the moon, the Earth looks like a big, spherical ball. However, to us who live on the Earth, on a small part of it, the Earth looks flat. We cannot see the whole Earth, we can only see a small part, which appears to be flat when we are on the Earth. Thus, while the Earth is a big round ball, it seems flat to us because we live only on a small part of it. |

of the texts is presented in Table 5. The sentences in bold were included only in the refutation texts.

Text 1 was a non-refutation text and explained that the Earth is spherical (non-categorical/non-refutation) (203 words). Text 2 refuted the belief that

**Table 6.** Trnaslation of the Questionnarie Used in Study 2

1. To which one of the two groups below does the 'Earth' best belong?
   Group 1: tree, rock, house, car / Group 2: planet, star, moon, sun
2. Why do you think the "Earth" belongs better with this group? (mention the group the child has selected)
3. Do you think that the Earth moves? ......................................................................
   If yes, how do you think the Earth moves? ........................................................
4. Draw the shape of the Earth as you think the Earth actually is.
5. Here is the picture of a house. This house is on the Earth. How come here the Earth is flat but before you draw it round? ........................................................

6. Look at the pitctures that follow. Describe what you see in each photo.

7. If you think that both pictures show the Earth, please explain why the Earth appears to be different in the two pictures ........................................................
8. If you walked for many days in a straight line, where would you end up? ...........
9. Is there an end or an edge to the Earth? Would you ever reach the end/edge of the Earth? ..................................................................................................
10. (If yes) Would you fall off that end/edge? ..................................................
11. Why? / Why not?.........................................................................................

the Earth is flat and stated that it is spherical (non-categorical/refutation) (256 words). Text 3 gave the categorical information that the Earth is an astronomical object and has all the characteristics of all the other astronomical objects (categorical/non-refutation) (192 words). Finally, Text 4 refuted the belief that the Earth is a physical object and presented the categorical information that it is an astronomical object in space (categorical/

refutation) (243 words). All texts were of comparable length and readability level according to the Flesch-Kincaid Grade Level Scale.[2]

The questionnaire was used as a pretest and as a posttest and it is shown in Table 6. Once again the questions were divided in two groups: (1) *explicit* questions for either the the categorical or the non-categorical texts (1 to 7), and (2) *inferential* questions for all the texts (8 to 11). The answers to the inferential questions were not explicitly stated in the texts but could be inferred from them.

### *3.1.3 Procedure*

The children in each of the four classrooms were randomly assigned to one of the experimental conditions. The pretest was administered first. When the pretest was collected, a written copy of one of the texts was distributed to all the children. They had 15 minutes to read it on their own. At the end of the reading period, the experimenter read the text aloud in order to make sure that the children could decode all the words. Then the written texts were removed and the posttest was administered.

### *3.1.4 Scoring*

A modification of the scoring key used in Study 1 was used. Two judges used the scoring key to score children's responses in all the questions independently. The judges' agreement was calculated at 93% [*Kendall's tau* $\tau=0.917$; $N=84$; $p<.001$]. All disagreements were discussed until a common score had been achieved on all the items. Children's responses to each of the 11 questions received a score of 1 if they were 'initial' if they were consistent with a naïve representation of the Earth and showed no exposure to scientific information, 2 if they revealed exposure to scientific information that was not understood, thus forming an alternative conception, and 3 if they were scientific. In case of 'No response' the mark was 0. Thus, for each student the total score could range from 0 to 33.

[2] 95.32 for Text 1, 90.29 for Text 2, 94.23 for Text 3, and 92.23 for Text 4.

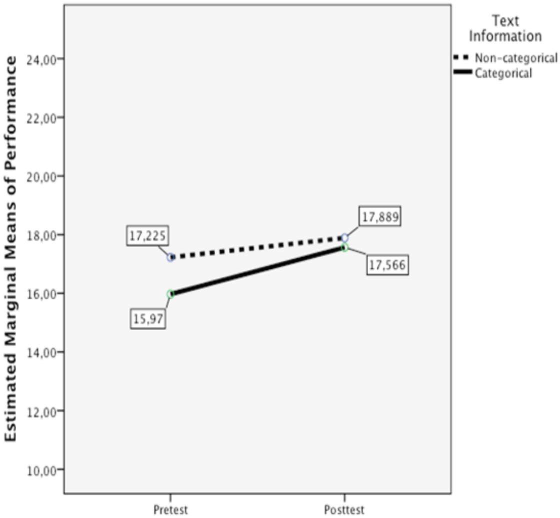


**Figure 3.** Children's Performance as a Function of Categorical Information

### 3.2 Results and Discussion

A one-way analysis of variance with text type as a between subject factor (Text1*Text2*Text3*Text4) was conducted on children's performance in the pretest. The results showed no statistically significant differences between the experimental groups in the pretest [$F(2,80)=1.784$, *n.s.*; $\eta^2=.003$]. Subsequently, children's responses to all the questions of the questionnaire were subjected to a repeated measures analysis of variance with categorical information (categorical*non-categorical) and the refutation format (refutation*non-refutation) as between subjects variables and time of test (pretest vs. posttest performance) as a within subjects variable.

The results showed a main effect for pretest-posttest performance [$F(1,80)=23.489$, $p<.001$; $\eta^2=.227$] due to the fact that all texts improved children's responses in the posttest. There was also a main effect for the categorical information variable [$F(1,80)=6.515$, $p<,05$; $\eta^2=.075$], showing that the categorical texts had greater impact on children's performance compared to the non-categorical texts. Finally, there was a statistically significant interaction between categorical information (categorical vs. non-categorical) and time of test (pretest-posttest) [$F(1,80)=4.005, p<,05; \eta^2=.079$] (Figure 3). This interaction was due to the fact that the texts presenting the categorical information had greater impact on children's responses in the posttest, compared to the texts with the non-categorical information, both in the case of the refutation and the non-refutation texts.

The above findings support the first hypothesis, that the texts with the categorical information would be more effective compared to the texts without the non-categorical information. In order to investigate the second and third hypotheses we conducted a repeated measures two-way ANOVA with text type (Text1*Text2*Text3*Text4) as a between subjects variable and time of test (pretest vs. posttest performance) as a within subjects variable. The results showed a main effect for pretest-posttest performance [$F(1,80)=23.489, p<.001; \eta^2=.227$], and a statistically significant interaction between text type and pretest-posttest performance [$F(3,80)=3.025, p<.05; \eta^2=.102$]. As can be seen in Figure 4, all conditions improved posttest performance, but the texts that included the categorical information were more effective than the texts that did not.

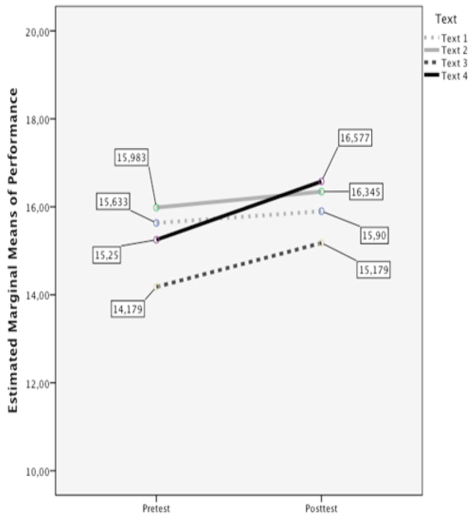


**Figure 4.** Children's Performance in all the Questions as a Function of Text type

**Table 7.** Mean Difference between Pretest and Posttest Performance in Children's Responses

| Texts | | Mean Difference | Std. Error | Significance |
|---|---|---|---|---|
| 1 | 2 | -.3971 | .71737 | n.s. |
| | 3 | 1.0881 | .83820 | n.s. |
| | 4 | -.1468 | .73134 | n.s. |
| 2 | 1 | .3971 | .71737 | n.s. |
| | 3 | **-1.14852*** | **.73406** | **p<.05** |
| | 4 | .2503 | .60919 | n.s. |
| 3 | 1 | -1.0881 | .83820 | n.s. |
| | 2 | **-1.4852*** | **.73406** | **p<.05** |
| | 4 | **-1.2349*** | **.74772** | **p<.05** |
| 4 | 1 | .1468 | .73134 | n.s. |
| | 2 | -.2503 | .60919 | n.s. |
| | 3 | **1.2349*** | **.74772** | **p<.05** |

A post-hoc analysis using the LSD test (Table 7) showed that the mean difference in children's responses between the pretest and the posttest was in favor of Text 4 (categorical/refutation) compared to Text 3 (categorical/non-refutation), supporting the second hypothesis, namely that the text that contained both the categorical information and the refutation would be more effective than the text that contained only the categorical information but not the refutation format.

The analysis also showed that the mean difference in children's performance between the pretest and the posttest was in favor of Text 3 (categorical/non-refutation) compared to Text 2 (non-categorical/refutation), supporting the third hypothesis, namely that the inclusion of categorical information is more effective than text format (refutation vs. non-refutation).

The results were further examined by analyzing children's performance in the inferential questions only (questions 8 to 11). A repeated measures two-way ANOVA with text type (Text1*Text2*Text3*Text4) as a between subjects variable and time of test (pretest vs. posttest performance) as a within subjects variable showed a main effect for pretest-posttest

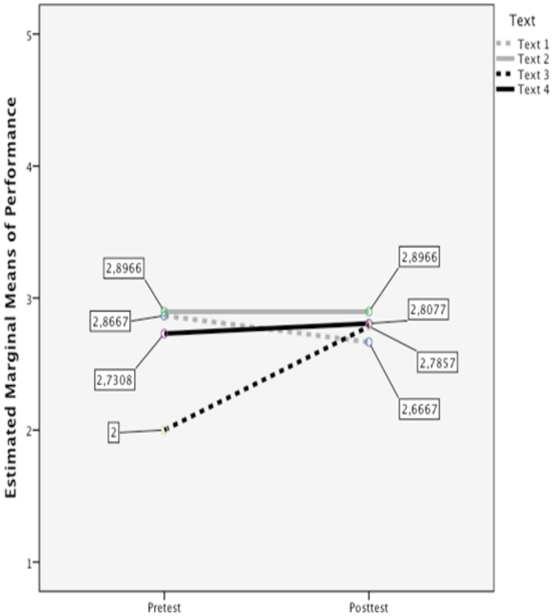


**Figure 5.** Children's Performance in the Inferential Questions as a Function of Text type

performance [$F(1,80)=4.547,\ p<.05;\ \eta^2=.054$] due to the fact that all texts improved children's responses in the posttest. A statistically significant interaction between text type and pretest-posttest performance was also obtained [$F(3,80)=5.978,\ p<.001;\ \eta^2=.183$] (Figure 5).

A post-hoc analysis using the LSD test showed that the difference in children's performance in the inferential questions was in favor of Text 4 (Categorical & Refutation) compared to Text 3 (Categorical & Non-refutation), supporting Hypothesis 2, and in favor of Text 3 (Categorical & Non-refutation) compared to Text 2 (Non-categorical & Refutation), supporting Hypothesis 3. The results of the post-hoc analyses are presented in Table 8.

**Table 8.** Mean Difference between Pretest and Posttest Performance in Children's Responses to the Inferential Questions

| Texts | | Mean Difference | Std. Error | Significance |
|---|---|---|---|---|
| 1 | 2 | -.1299 | .16613 | n.s. |
| | 3 | .3738 | .19411 | n.s. |
| | 4 | -.0026 | .16036 | n.s. |
| 2 | 1 | .1299 | .16613 | n.s. |
| | 3 | **-.5037*** | **.16999** | **p<.005** |
| | 4 | .1273 | .14108 | n.s. |
| 3 | 1 | -.3738 | .19411 | n.s. |
| | 2 | **-.5037*** | **.16999** | **p<.005** |
| | 4 | **-.3764*** | **.17316** | **p<.05** |
| 4 | 1 | .0026 | .16936 | n.s. |
| | 2 | -.1273 | .14108 | n.s. |
| | 3 | **.3764*** | **.17316** | **p<.05** |

## 4. Genenral Discussion

The purpose of the present research was to investigate the hypotheses that the amount of relevant information and the kind of information refuted in refutation texts influences their effectiveness. With respect to the first hypothesis, there was no clear support that the amount of relevant information refuted may affect the effectiveness of refutation texts. In the first experiment, only Text 3 produced better results than Text 1 and Text 2 in some of the conditions; Text 3 was found to be more effective than Text 1 in children's responses in all the questions of the questionnaire and it was more effective compared to both texts in children's responses in the inferential questions of the questionnaire. However, Text 3, which gave more information than the other two texts, also included the categorical information. This brings us to our second hypothesis regarding the kind of information presented in refutation texts.

The results of the two experiments are much stronger with respect to the influence of the second variable manipulated, namely the kind of information that was refuted. In Experiment 1, Text 3, which included the categorical information, was found to be more effective than the other two texts, particularly in children's responses to the inferential questions. Experiment 2, which controlled for the amount of information refuted in the texts and manipulated only the kind of information, clearly showed that the texts that included the categorical information were more effective than the texts that did not. The children who read the texts that included the information that the Earth is an astronomical object in space improved their performance in the posttest more compared to their peers who read texts that did not include the categorical information.

As expected, the categorical refutation text was more effective than the categorical non-refutation text, confirming once more the importance of text format (refutation vs. non-refutation) in scientific expository texts, in agreement with existing research (Broughton & Sinatra, 2010; Diakidoy, Kendeou, & Ioannides, 2003; Dole, 2000; Guzzetti, et al., 1997; Kendeou & van den Broek, 2005, 2007; Mikkilä-Erdmann, 2002; O'Reilly & McNamara, 2007). However, another important result of the second experiment was that the categorical non-refutation text improved children's responses in the posttest more than the non-categorical refutation text. This result indicates that the inclusion of categorical information in texts might be more important than text format (refutation vs. non-refutation) in facilitating the understanding of scientific information. This result needs to be replicated with using more examples from other science domains.

A possible explanation of the facilitating effect of the categorical information is that this type of information is generic and carries with it a great deal of implicit information that can be used by the learner to guide new learning. In the present case, the inclusion of the categorical information that the Earth is not a physical but an astronomical, with the characteristics of other astronomical objects, seems to have led to a non-egocentric representation of the Earth as a spherical planet in space, preventing the creation of alternative conceptions and allowing children to draw the correct conclusions when answering the inferential questions. The results are consistent with research showing that re-categorization is an important part of the process of conceptual change both in observational astronomy (Vosniadou & Skopeliti, 2005) and in other subject matter areas like physics and chemistry (Chi, 2013).

A limitation of the present study is that only one domain of science was used. The result needs to be replicated using other science domains. Another limitation of the study is that it investigated only short-term improvements in children's understanding of the scientific information. It is considered to be useful to have information coming not only from an immediate posttest but also from a delayed posttest in order to determine the lasting learning effects of these manipulations. Nevertheless, the finding of the present research regarding the importance of the categorical information has implications that need to be considered by curriculum designers, authors of science text, and, of course, teachers.

Assigning a concept to a new category is one of the most difficult conceptual changes to achieve in the process of learning science (Chi, 2013; Chi & Roscoe, 2002; Thagard, 2013; Vosniadou & Skopeliti, 2014). The present research indicates that texts that make explicit reference to the scientific category to which a concept belongs are more effective than texts that do not. In the case of the Earth concept it was not too difficult to write texts that included the information that the Earth is an astronomical object in the present texts, because the children had already formed the category of astronomical objects. However, it might be more difficult to refer to the scientific category in a text when this category is new and has to be created. For example, reference to the category 'interactions' in a text that explains concepts like force, or heat, which are initially categorized as substances or properties of objects might not carry much meaning or explanatory power for a student. Future research will need to investigate how categorical information can be best included in science texts, particularly when the scientific category is not likely to exist in the repertoire of the student.

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