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Representation of the ozone layer in children's trade books about ozone layer depletion: An analysis of written texts in Greece

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ABSTRACT

Although children's trade books are considered effective tools for introducing children to science content, studies have concluded that children form alternative ideas about science topics when the information presented in children's books is inaccurate. The aim of the present study is to examine how stratospheric ozone is represented in children's books about ozone layer depletion and whether these representations could foster alternative ideas about the topic. A total of nine books, published for preschool and primary school-aged children in Greece, were selected for analysis. Each of the nine books was analyzed using qualitative content analysis. The cognitive elements and information provided by the texts concerning the nature and role of ozone were organized into categories and compared with the scientific consensus view. The results revealed that all books identified in this study provided information about the nature of ozone while two books presented its role in the atmosphere. However, the topic was inadequately covered as misrepresentations about the position, distribution, and origin of ozone, its role in the atmosphere and the mechanism preventing UV radiation from reaching the Earth were recorded. Even though children's books support science teaching and learning, the limitations appearing in the books require teachers to correct the texts or use additional scientifically accurate material to teach about the ozone layer and its depletion adequately and accurately. Collaboration between publishing companies, authors, and science consultants is recommended for improving the representation of science topics in children's literature.

Keywords: children's books, ozone layer, alternative ideas, science education, environmental education, content analysis

INTRODUCTION

The decrease in stratospheric ozone concentrations caused by increasing anthropogenic gas emissions is recognized as one of the Earth's major environmental problems (Cordero, 2000; Miller & Spoolman, 2019). The depletion of the ozone layer and its detrimental consequences on human health and the environment have attracted public attention and generated worldwide concern among people (Gungordu et al., 2017). This is apparent by the inclusion of this environmental problem in school curricula and by the fact that it has received extensive media coverage (Christidou & Koulaidis, 1996). Electronic and print media appear to be selected by children, teachers, and the general public to obtain information about the environment, influencing the development of environmental knowledge (Dove, 1996; Khalid, 2001). However, the information communicated through mass media is sometimes incompatible with the scientific consensus view, leading to confusion and alternative ideas on environmental issues (Dove, 1996; Gungordu et al., 2017; Khalid, 2001). Gungordu et al. (2017) analyzed 219 websites related to the ozone layer and found that these websites provided inaccurate and misleading information that could foster alternative ideas among students. Besides the mass media, children's literature has also begun to cover themes about nature and environmental issues, after the emergence of environmentalism in the USA during the second half of the 20th century (Echterling, 2016; Wells & Zeece, 2007).

Children's trade books are considered an important tool for teaching and learning in various content areas, such as social sciences, life sciences, physical education, and health (Pantaleo, 2002; Ross, 1994). Trade books are those books offered for sale to the general public, unlike textbooks designed for a specific group, such as primary school children (Schroeder et al., 2009; Schussler, 2008). The growing trend of integrating reading and writing into science instruction has encouraged the use of science trade books in classroom instruction (Butzow & Butzow, 2000; Rice, 2002; Schussler, 2008). Donovan and Smolkin (2002) identify four different

genres of science trade books: storybooks, narrative or non-narrative informational texts, and dual-purpose books. Many researchers argue that children's trade books, especially fiction books, can also be effectively integrated into environmental education (Freestone & O'Toole, 2016; Wells & Zeece, 2007; Williams et al., 2012). Even though stories would not replace authentic childhood experiences acquired in the natural environment, the use of children's books in environmental education seems to promote pro-environmental values as children often uncritically accept the information from stories (Freestone & O'Toole, 2016). Listening to or reading a storybook may be beneficial for children as they immerse themselves in the story, relate to the characters' emotions, and draw connections between themselves and environmental problems that inspire them to find solutions and foster empathy toward other creatures (Butzow & Butzow, 2000; Monhardt & Monhardt, 2000). Besides the development of environmental values, storybooks can also be used as an instructional tool to enhance science teaching and children's acquisition of environmental and scientific concepts (Hsiao & Shih, 2016; Pringle & Lamme, 2005; Williams et al., 2012). Storybooks present content knowledge in a narrative form that allows children to understand and better remember abstract and difficult science concepts (Butzow & Butzow, 2000; Morrow et al., 1997). In addition, the familiar language and the storyline provide readers with a meaningful and familiar context that facilitates children's understanding and maintains children's interest (Butzow & Butzow, 2000; Pringle & Lamme, 2005; Ross, 1994).

While researchers and educators advocate that children's literature is an effective instructional tool in both science and environmental education (Monhardt & Monhardt, 2000; Morrow et al., 1997; Saul & Dieckman, 2005; Wells & Zeece, 2007), questions have arisen regarding the scientific accuracy of its content and whether it may contribute positively or negatively to children's subsequent learning. Mayer (1995) read aloud the book entitled "Dear Mr. Blueberry" to 16 students from kindergarten through third grade and concluded that few children learned new facts about whales. On the other hand, some of them constructed erroneous ideas as a result of the errors and inaccuracies in the book's content. Similarly, Rice (2002) read five inaccurate science books about whales to two classes of second graders and to one class of fourth-graders to investigate whether children were capable of separating fact from fiction. The study demonstrated that, although children had prior knowledge about whales, many participants were unable to discriminate between accurate and inaccurate information. Thus, they acquired incorrect ideas. Both studies argued that children not only learn scientific information from children's books, but also develop alternative ideas about science topics when errors and inaccuracies are embedded in textual and/or visual representations. Teachers and parents should be cautious in selecting children's literature and critically examine the scientific accuracy of the content (Atkinson et al., 2009; Mayer, 1995; Sudol & King, 1996).

Researchers from various disciplines have examined the accuracy of science content in both fiction and nonfiction children's trade books addressing different topics and themes, such as whales and dolphins (Beaumont et al., 2017), Testudines (Beaumont et al., 2019), the moon (Rice & Rainsford, 1996; Trundle & Troland, 2005; Trundle et al., 2008), plant reproduction (Schussler, 2008), animals (Marriott, 2002), and the nature of science (Ford, 2006). These studies reported errors and inaccuracies in various scientific aspects of children's books that may reinforce or support inaccurate conceptions. After having reviewed 73 science trade books that were suitable to be used in the teaching of science concepts in preschool classrooms, Sackes et al. (2009) recorded misconceptions, anthropomorphism, and inaccurate illustrations in all of the content areas under study (physical science, earth and space science, life science concepts). Rice and Rainsford (1996) evaluated 50 children's books with various science themes commonly used in primary schools. They documented implicit and explicit misinformation in the texts and errors in illustrations. For example, mushrooms were identified as plants, and quicksand was depicted as only found in the jungle. Children's books with environmental themes may also contain incorrect and misleading science content in favor of excitement and readability (Meyer, 2002). However, the literature has not yet investigated how stratospheric ozone is being portrayed in children's books about ozone layer depletion and whether these representations could contribute to the construction of alternative ideas in children.

The present study aims to examine the scientific accuracy of written representations of the ozone layer in children's literature about ozone layer depletion found in Greece. The ozone layer was determined as the focus of this study since its understanding involves abstract concepts and complex processes that are not included in children's direct experiences (Christidou & Koulaidis, 1996; Leighton & Bisanz, 2003). Furthermore, low levels of understanding and a variety of alternative ideas about the ozone layer and its depletion have been identified among children and adults by previous studies in different countries (e.g., Boyes & Stanisstreet, 1997; Boyes et al., 1995; Christidou & Koulaidis, 1996; Christidou et al., 1997; Daskolia et al., 2006; Leighton & Bisanz, 2003, Migdanalevros & Kotsis, 2021; Papadimitriou, 2004). For example, students of various educational levels attribute global warming to ozone layer depletion (Boyes & Stanisstreet, 1993; Boyes et al., 1999; Francis et al., 1993; Kilinc et al., 2008; Pekel & Ozay, 2005; Pruneau et al., 2001) and believe that the greenhouse gases harm the ozone layer (Boyes & Stanisstreet, 1994; Pekel & Ozay, 2005). These alternative ideas might come from the misinformation on Internet-based media (Gungordu et al., 2017) as well as the limited coverage of the environmental issue in the curriculum across all educational levels (Migdanalevros & Kotsis, 2021). Regarding the coverage of the ozone layer and its depletion in the Greek science curriculum, the phenomenon was completely absent from primary education. Since the introduction of the new curriculum in 2003, ozone layer depletion has been incorporated in a primary school textbook. We found that the 6th grade geography's textbook (Koutsopoulos et al., 2019) devotes only a small text to this environmental problem in the chapter "The atmosphere" in which the Earth's atmospheric layers are introduced and the role of the ozone layer is briefly described. The text explains that ozone is a gas in the stratosphere. This gas absorbs the dangerous sunrays, known as ultraviolet, that damage humans, plants, and animals. Even

though ozone layer depletion is briefly mentioned in a primary school textbook, according to the Greek primary school curriculum and the official teaching instructions from the Ministry of Education, there is no mandatory teaching of the above-mentioned chapter. Considering that primary school students collect information about this topic from various indirect and extracurricular sources, such as television, the Internet, and books, and that there is the possible potential for children's trade books to communicate alternative ideas about science concepts and phenomena (Mayer, 1995; Rice, 2002), it seems relevant to critically examine how children's trade books represent the ozone layer and whether these books could be sources of alternative ideas.

In this context, the nature and role of stratospheric ozone in the atmosphere are chosen as the focus of this study. The following research questions have been designed:

1. How is the nature of the ozone layer portrayed in texts of children's trade books about ozone layer depletion?
2. How is the role of the ozone layer portrayed in texts of children's trade books about ozone layer depletion?
3. What potential alternative ideas, if any, about the nature and role of ozone might primary school children construct or reinforce by reading or listening to these books?

The data from this study will provide teachers, parents, and other specialists who intend to use these books in the classroom with an insight into the written representations of the ozone layer and whether these representations are accurate or not as well as their potential effect on primary students' understanding of ozone.

MATERIALS AND METHODS

Sample Selection

To identify the books that would be examined in the present study, search engines on the websites of 71 publishing companies were used. 60 of publishing companies were listed in online catalogue with publishers available at http://www.mikrosanagnostis.gr/thema-oikologia-vivliografia.asp. This catalogue is comprised of publishers that have published children's books about the environment and have accepted the invitation from the National Book Center of Greece to participate in the compilation of the catalogue. The remaining 11 publishers were detected in four public libraries in northern Greece. In case that a publishing company did not have a website, we used the electronic book database BIBLIONET, that contains all Greek books in print, to identify children's books published by this company. The search terms *"ozone"*, *"ozone layer"*, *"ozone layer depletion"*, and *"air pollution"* were used to identify the books. The following criteria were applied to shortlist the books for the present study:

(1) storybooks and dual-purpose genre,

(2) written for preschool (age three to six) and primary school-aged children (age six to 12),

(3) ozone layer depletion involved in the story, and

(4) available for lending by local public libraries or purchase through online bookstores in Greece.

The availability in public libraries or on the websites of bookstores was set as a selection criterion since schools and families commonly use these resources to collect books for children. The study sample is representative of the books that a primary school teacher or parent might obtain when selecting children's books about ozone layer depletion in Greece.

Based on the aforementioned criteria, eight publishing companies were found to have published nine children's books about ozone layer depletion. Accordingly, nine children's books published in Greece between 1999 and 2011, which included cognitive elements about the stratospheric ozone and its depletion, were examined. The majority of the books were categorized as storybooks (n=6) while the remaining ones were dual-purpose books (n=3). Although the dual-purpose books contained non-narrative information, in the present study only the story pages were examined. According to the publishers' recommended target ages, four of the nine books were suitable for the age group three to six and upwards, and five books addressed children of six and upwards.

Data Collection

The data analysis followed a qualitative content analysis approach. As the aim of the study was to isolate specific content dimensions of the material and summarize them, a combination of deductive and inductive procedures was needed. The content structuring by Mayring (2014, 2021) was applied to develop a theory-led category system. First, a list of themes was developed to code the content of the texts. Two main codes were derived deductively from the theoretical considerations and the study's research questions to capture how each of the nine books represented:

(1) the nature of ozone (code 1) and

(2) the role of ozone (code 2).

For each code, coding rules that determined the relevant material from the texts were formulated and anchor examples that provided verbatim examples of quotes taken from the texts reviewed were identified (**Table 1**). All anchor quotes were translated into English by the first author. Then the story pages were read independently line by line several times by the same two researchers. All text passages that fit either the broad category of "the nature of ozone" (code 1) or the broad category of "the role of ozone" (code 2) were recorded using the MAXQDA software (version 2020). Subsequently, content that was not relevant to the nature or the role of ozone was excluded from the analysis. In the event of differences between the two researchers in the recorded passages, the texts were reviewed again, and disagreements were discussed until an agreement was reached.

After that, the extracted passages resulting from the first coding step underwent coding to identify key themes about the nature and role of stratospheric ozone integrated into them as well as summarizing per category. Inductive category formation (Mayring, 2014, 2021) was applied to arrive directly at a category system emerging from the material itself. The extracted passages within the two broad categories (code 1, code 2) were read repeatedly and sorted until main categories and subcategories emerged from the data. For the inductive category formation, specific criteria for the selection of

Table 1. The coding guideline

Code	Code description	Anchor example
1. The nature of ozone	This code is used when a passage provides cognitive elements & information about nature of stratospheric ozone.	*"Several kilometers above the Earth's surface lies the ozone layer. The ozone [...] wraps around the Earth"* (Papatheodoulou, 2008). *"The ozone in atmosphere gets destroyed & recreated back from the beginning, thus there is always enough to protect us"* (Papatheodoulou, 2008).
2. The role of ozone	This code is used when a passage provides cognitive elements & information about role of stratospheric ozone.	*"-This mantle will protect creatures that live on your surface from my excessive heat, explained the Sun"* (Tasakou, 2002). *"This layer does not let the Sun's harmful ultraviolet rays reach the Earth & damage the plants & the animals, & thus the Earth wears its protective sunglasses"* (Papatheodoulou, 2008).

categories and levels of abstraction were established for each code in advance. In this study, categories were formulated as "cognitive element and information concerning the nature of ozone" (selection criterion for code 1) and "cognitive element and information concerning the role of ozone" (selection criterion for code 2). In addition to the selection criteria, the specification of the abstraction levels, which establishes how specific or general the category formation should be, was required. The levels of abstraction were formulated as "concrete aspects relevant to the nature of ozone" (code 1) and "concrete aspects relevant to the role of ozone and its mechanism of action" (code 2). In accordance with the content analytical rules for inductive category formation, the coding unit, which is the smallest component of the material that can be coded, was set to clear meaning component (seme) in the text. The context unit, which serves as the background for the coding decision, was specified as the respective children's book. By definition, the recording unit was set to the entire text material, in this case all children's books. After the establishment of the aforementioned content analytical rules, the books were analyzed line by line. When a text segment corresponded to selection criteria, a category that reflects the content was formed at the level of abstraction. The next time eligible text segment was found, it was checked if it could be subsumed to an existed category or if a new category had to be formulated. After several rounds of analysis of the data, the main categories/themes were established. For a more detailed analysis, the main categories were subdivided into smaller specific subcategories in order to provide with specific descriptions relevant to the main categories found in passages, allowing an in-depth analysis within each theme. The inductively developed categories and subcategories were transferred to the coding guide accompanied by anchor examples. To evaluate the reliability of the analysis, we calculated interrater reliability. After the first coder had formulated the category system, the second coder related the passages to the argument categories. Cohen's kappa was calculated for each category. Inter-rater agreement was high with kappa values ranging from 0,86 to 0,91. Differences between the two coders were discussed until an agreement was reached.

To identify potential alternative ideas about the nature and role of ozone that primary school students might construct when reading or listening to the books under study, the passages within each subcategory were reviewed a second time and compared with the scientific consensus view. The passages were read independently multiple times by the same two researchers to determine if the written representations of the stratospheric ozone were scientifically accurate or inaccurate. In case a written representation was defined as being at odds with the scientifically accepted view, examples of potential alternative ideas were recorded. All disagreements about the accuracy of the coded passages and the potential alternative ideas between researchers were discussed until an agreement was reached.

RESULTS

Together a total of 30 statements about the nature and role of ozone were identified in the texts and analyzed via content analysis. The content analysis involved coding the data, identifying their theme, organizing them into categories and subcategories, and interpreting the findings. The results of the present analysis are presented. We list the categories and subcategories about the nature and role of ozone, anchor examples taken from the material reviewed together with examples of the possible alternative ideas that might be constructed or reinforced by primary school students after the exposure to the misrepresentations found in the texts.

How the Nature of the Ozone Layer is Represented

After analysis of the texts from each of the nine books, 22 passages about the nature of ozone were identified and isolated. These passages were then organized into two main categories based on their theme:

1.1 the position and distribution of ozone (n=16) and

1.2 the origin and composition of ozone (n=6) (**Table 2**).

The 16 passages within the main category of the position and distribution of ozone (1.1) were analyzed and placed into three subcategories based on where ozone is located and how ozone is distributed in the atmosphere. The seven passages that fell into the first subcategory (1.1.1) described the stratospheric ozone as a *layer*, a *mantle*, or an *umbrella* in the Earth's atmosphere. According to them, ozone is located *"several kilometers above the Earth's surface"*, *"around the Earth"*, *"in the higher layers of the Earth's atmosphere"*, *"high in the sky"* or below the stratosphere. For example, one book says: *"Several kilometers above the Earth's surface lies the ozone layer. The ozone [...] wraps around the Earth."* (Papatheodoulou, 2008), and another states: *"[...]* (the exhaust gases) *started to puncture the ozone mantle to rise even higher. Initially they opened small holes and escaped upwards, to the so-called stratosphere."* (Tasakou, 2002). The second subcategory (1.1.2) consisted of one passage, according to which ozone forms a layer, like a *shield* or a *filter*, in front of the Sun. The book states: *"The ozone layer is a protective shield, a filter, located in front of the Sun [...] Without this filter [...]"* (Shomei, 1999). In the eight passages of the third subcategory (1.1.3), the

Table 2. The coding scheme for the nature of stratospheric ozone

Categories	Subcategories	Anchor examples	Possible alternative ideas	NCO	NDT
1.1 Position & distribution of ozone				16	9
	1.1.1 The ozone forms a layer in the Earth's atmosphere	*"[…]* (exhaust gases) *started to puncture the ozone mantle to rise even higher. Initially they opened small holes & escaped upwards, to the so-called stratosphere"* (Tasakou, 2002).	Thinking that the ozone layer exists right below the stratosphere.	7	4
	1.1.2 The ozone forms a layer in front of the Sun	*"The ozone layer is a protective shield, a filter, located in front of the Sun […] Without this filter […]"* (Shomei, 1999).	Thinking that ozone forms a layer in front of the Sun.	1	1
	1.1.3 The ozone is uniformly distributed in the Earth's atmosphere	*"[…] he saw a tiny hole in the air that surrounds the Earth…"* (Papadopoulou, 2008).	Thinking that ozone is uniformly spread into the atmosphere.	8	4
1.2 Origin & composition of ozone				6	2
	1.2.1 The ozone layer was given to the Earth by the Sun	*"To see how much I love you, I am going to give you one more gift: I will give you a unique, amazing mantle. Indeed, straightaway the Sun covered the Earth with renowned ozone mantle"* (Tasakou, 2002).	Thinking that stratospheric ozone is derived from the Sun.	3	1
	1.2.2 The cotton is turned into ozone by a wizard	*"The magician took away his magic wand […] he made with it some gestures like a conductor in front of the cotton & the cotton …-It disappeared, said Kathrine. -It did not disappear. It turned into fresh, perfectly clean ozone. This is something that science would never have made it without my magic tricks."* (Papatheodoulou, 2008)	Thinking that a magician can turn the cotton into ozone.	1	1
	1.2.3 The ozone gets destroyed & recreated in the atmosphere	*"The ozone in the atmosphere gets destroyed & recreated back from the beginning, thus there is always enough to protect us"* (Papatheodoulou, 2008).	Thinking that the ozone gets destroyed & recreated in the atmosphere without contribution of other factors (UV radiation)	1	1
	1.2.4 The ozone is a chemical compound composed of oxygen	*"[…] a chemical compound made of oxygen, just like the one we breathe […]"* (Papatheodoulou, 2008).		1	1

Note. NCO: Number of category occurrences & NDT: Number of different texts

stratospheric ozone was seen as uniformly spread around the Earth, into the atmosphere, the sky, or the air. For instance, one book writes: *"[…] the atmosphere had holes!"* (Iliopoulos, 2009). Another states: *"[…] he saw a tiny hole in the air that surrounds the Earth…"* (Papadopoulou, 2008). These passages used terms *atmosphere*, *sky*, or *air* instead of *ozone layer/mantle* and represented the stratospheric ozone as not being concentrated at a certain altitude in the Earth's atmosphere.

The second main category: the origin and composition of ozone (1.2) consisted of six passages that were organized into four subcategories based on their theme. According to the three passages of the first subcategory (1.2.1), the ozone layer was given to the Earth by the Sun. The book that includes these passages states: *"To see how much I love you; I am going to give you one more gift: I will give you a unique, amazing mantle. Indeed, straightaway the Sun covered the Earth with the renowned ozone mantle."* (Tasakou, 2002). The passage in the second subcategory (1.2.2) stated that a wizard turns the cotton into ozone. The passage says: *"The wizard took away his magic wand […] he made with it some gestures like a conductor in front of the cotton and the cotton…-It disappeared, said Kathrine. -It did not disappear. It turned into fresh, perfectly clean ozone. This is something that science would never have made it without my magic tricks."* (Papatheodoulou, 2008). As stated in the passage of the third subcategory (1.2.3), the ozone gets destroyed and recreated in the atmosphere. The specific factors that contribute to this process were not mentioned. The book says: *"The ozone in the atmosphere gets destroyed and recreated back from the beginning, thus there is always enough to protect us."* (Papatheodoulou, 2008). The passage in the last subcategory (1.2.4) referred to the chemical composition of ozone. The book describes ozone as *"[…] a chemical compound made of oxygen, just like the one we breathe […]"* (Papatheodoulou, 2008). According to this passage, ozone is a chemical compound composed of oxygen.

How the Role of Ozone is Represented

Of the nine children's books reviewed for the present study, four books included eight passages about the role of stratospheric ozone. These eight passages were then organized into two main categories based on the description of the role of the ozone layer in the atmosphere:

2.1 protection, without referring to the ozone layer's mechanism of action (n=6) and

2.2 protection with reference to the ozone layer's mechanism of action (n=2) (**Table 3**).

The first main category (2.1) consisted of six passages, according to which the ozone layer provides protection for the Earth, humans, plants, or living organisms without making explicit reference to the exact mechanism of this protection. This category was further broken down into three subcategories based on the factor from which the ozone layer provides protection. The three passages in the first subcategory (2.1.1) noted that ozone protects the Earth and living organisms. No textual reference was made to the factors against, which the ozone layer offers protection. For example,

Table 3. The coding scheme for the role of stratospheric ozone

Categories	Subcategories	Anchor examples	Possible alternative ideas	NCO	NDT
2.1 Protection, without referring to the ozone layer's mechanism of action				6	3
	2.1.1 Protection against unspecified factor	*"-The ozone mantle did not protect me! It was you that it protected […]"* (Tasakou, 2002).		3	3
	2.1.2 Protection against the harmful solar ultraviolet radiation or harmful ultraviolet sunrays	*"The ozone layer is a protective shield […] it protects the Earth, humans, and plants from the harmful ultraviolet radiation. Without this filter, there would be no life on Earth"* (Shomei, 1999).		2	2
	2.1.3 Protection against the Sun's heat	*"-This mantle will protect the creatures that live on your surface from my excessive heat, explained the Sun"* (Tasakou, 2002).	Thinking that stratospheric ozone protects Earth & living organisms from heat coming from the Sun.	1	1
2.2 Protection with reference to the ozone layer's mechanism of action				2	
	2.2.1 The ozone layer prevents ultraviolet radiation from reaching the Earth	*"This layer does not let the Sun's harmful ultraviolet rays reach the Earth & damage the plants and the animals, & thus the Earth wears its protective sunglasses"* (Papatheodoulou, 2008).	Thinking that the role of the ozone layer is to prevent the UV radiation from reaching the Earth.	1	1
	2.2.2 The ozone layer blocks the dangerous sun rays	*"The ozone, so they say, is the Earth's umbrella. It protects the Earth from harmful sunrays. It does not let them pass & harm anyone"* (Michailaki-Arfara, 2008).	Thinking that the role of the ozone layer is to block the sun's rays in general.	1	1

Note. NCO: Number of category occurrences & NDT: Number of different texts

one book states: *"-The ozone mantle did not protect me! It was you that it protected […]"* (Tasakou, 2002) and another book mentions: *"[…] so as there is always enough* (ozone) *to protect us."* (Papatheodoulou, 2008). These passages presented the ozone layer as a protective layer, but there was no stated connection between the ozone layer and the Sun's radiation. According to the two passages in the second subcategory (2.1.2), the ozone layer protects the Earth from the harmful ultraviolet solar radiation or harmful ultraviolet sunrays. For example, one story says: *"The ozone layer is a protective shield […] it protects the Earth, humans, and plants from the harmful ultraviolet radiation. Without this filter there would be no life on Earth."* (Shomei, 1999). The passages specifically mentioned ultraviolet radiation, but no explanation was given as to how the protection occurs (by absorbing, reflecting, or filtering UV radiation). The passage in the third subcategory (2.1.3) indicated that the ozone layer protects the living organisms from the Sun's heat. The book states: *"-This mantle will protect the creatures that live on your surface from my excessive heat, explained the Sun"* (Tasakou, 2002). As implied in this book, the function of the ozone layer is to prevent global warming.

The second main category (2.2) consisted of two passages that portrayed the role of the ozone layer in the atmosphere along with its mechanism. This category was further subdivided into two subcategories based on the type of radiation from which ozone provides protection. As mentioned in the first subcategory passage (2.2.1), the ozone layer prevents ultraviolet radiation from reaching the Earth. The book states: *"This layer does not let the Sun's harmful ultraviolet rays reach the Earth and damage plants and animals, and thus the Earth wears its own protective sunglasses"* (Papatheodoulou, 2008). The passage in the second subcategory (2.2.2) mentioned that the ozone layer blocks the dangerous sunrays, without referring to the specific type of these rays. The book writes: *"The ozone, so they say, is the Earth's umbrella. It protects the Earth from harmful sunrays. It does not let them pass and harm anyone."* (Michailaki-Arfara, 2008). Both passages stated that the role of the ozone layer is to protect the Earth by blocking the UV radiation or the dangerous sunrays in general.

DISCUSSION

How the Nature of Ozone is Represented

One of the research questions of the present study was to ascertain how the nature of ozone is being described in a sample of children's books about ozone layer depletion. The findings demonstrated that each of the nine books of the study incorporated information about the nature of ozone. All books included passages about the position and distribution of ozone and two books included passages about its origin and composition.

Regarding the position and distribution of stratospheric ozone (1.1), three different options were presented across all nine books. Almost half of the books (n=4) described ozone forming a thin layer that surrounds the Earth. The terms *layer*, *shield*, and *umbrella* were used to portray the distribution of ozone in the Earth's atmosphere, high up in the sky or a few kilometers above the Earth's surface. Even though one of these four books referred to the stratosphere, it did not mention that ozone is concentrated in the lower part of this layer. On the contrary, it indicated erroneously that ozone exists right below the stratosphere. In the case of one book of the sample, ozone is not localized in the Earth's atmosphere, but it seems to form a layer in front of the Sun. In the remaining four books, ozone appeared to be uniformly spread into the Earth's atmosphere. These books implied that the atmosphere is a homogeneous mixture and ozone is uniformly distributed into it. Obviously, none of the books surveyed introduced an accurate localization of stratospheric ozone. Most ozone (about 90%) is in fact concentrated in the stratosphere, about 10-16 kilometers above the Earth's surface, and extends up to about 50 kilometers altitude. The region in the stratosphere where ozone presents the highest concentration is known as the ozone layer (Hegglin et al., 2015). Four books were in greater proximity to the scientific consensus view about the distribution of ozone. According to them, ozone forms a layer in the atmosphere around the Earth, but its accurate location in the stratosphere was not mentioned.

The recorded errors and inaccuracies, found by the survey, reflect some of the alternative ideas about the nature of ozone amongst school students noted in the literature. Research into the understanding of the ozone layer and ozone layer depletion by preschool and primary school-aged children has been limited. However, Christidou and Koulaidis (1996) documented primary school pupils' models (11- to 12-year-old) of the ozone and its depletion and found that most of the students could understand that ozone is concentrated in a layer around the Earth (78%). On the other hand, many of them (17%) appreciated that ozone is uniformly spread into the atmosphere, and some (5%) claimed that ozone forms a layer surrounding the Sun. The same or relevant alternative ideas were recorded in five of the nine books examined in this study. Thus, reading or listening to these books, which localize the ozone layer in front of the Sun, below the stratosphere, or uniformly distributed into the Earth's atmosphere, could possibly lead children to the construction or reinforcement of alternative ideas about the distribution and localization of ozone.

Concerning the origin and composition of ozone (1.2), four different options were presented across two books. One book stated that the Sun developed the ozone layer and gave it as a gift to the Earth. The other book stated that:

(a) a wizard can turn the cotton into ozone,

(b) ozone gets destroyed and recreated in the atmosphere, and

(c) ozone is a chemical compound formed by oxygen.

The last statement seems to be in accordance with the scientific consensus view, according to which ozone is a gas composed of three oxygen atoms (Hegglin et al., 2015). The statement about the destruction and recreation of ozone might support alternative ideas due to the omission of the crucial role that UV radiation plays in this process. Moreover, the use of fantasy and magic in the descriptions of the origin of ozone might foster the alternative ideas that ozone has been made by the Sun and that the cotton can be converted into ozone. The results indicate that in the last book passages conforming to the scientific view coexist with passages that embed fantasy, magic, and omissions.

How the Role of Ozone is Represented

Another research question of the present study was to ascertain how the role of ozone is being described in a sample of children's books about ozone layer depletion. One initial finding was that information about the role of ozone was embedded in four of the nine books of the sample. Eight passages across four books mentioned that the ozone layer provides the Earth and living organisms with protection. The particular mechanism by which the ozone layer protects the Earth was not recorded in the children's books. Two books stated in an oversimplified way that the ozone layer prevents ultraviolet radiation or harmful sun's rays from entering the earth, without referring to the absorption mechanism of UV radiation. Christidou and Koulaidis (1996) found a range of misunderstandings in children (11- to 12-year-old) about the role of ozone. Most of the participants considered that ozone has the property of stopping UV radiation, while a small amount of them (10%) conceived ozone as a reflective medium. None of the students could explain accurately how ozone stops ultraviolet radiation from reaching the Earth. The books' instances found by the present survey reflected some of the students' descriptions noted in the Christidou and Koulaidis (1996) study, relating particularly to the lack of the absorption mechanism of UV radiation by the ozone layer.

Except for three passages of two books, which mentioned that the ozone layer protects the Earth from ultraviolet radiation or ultraviolet rays (2.1.2, 2.2.1), the remaining passages either omitted the factor from which the ozone layer provides protection or mentioned that the ozone layer protects the Earth from the *excessive heat* (2.1.3) or *harmful sunrays* (2.2.2). In two books, the terms *heat* and *sunrays* were used as equivalent to UV radiation. Empirical studies have reported that children have difficulties in distinguishing between UV and other forms of solar radiation. In particular, they do not make any conceptual differentiation between heat rays and UV rays (Boyes & Stanisstreet, 1998; Christidou & Koulaidis, 1996; Österlind, 2005), while only a few children make connections between the ozone layer and the ultraviolet radiation (Christidou & Koulaidis, 1996; Plunkett & Skamp, 1994). The younger children refer to sunrays in general and then at the age of 13- to 14-year-old start to mention the ultraviolet rays (Plunkett & Skamp, 1994). According to Andersson and Wallin (2000) study, the proportion of children using the terms accurately increases with age. At first, children use the terms *sun* and *sunlight*, then the term *radiation*, and at the end the term *ultraviolet* or *UV radiation*. The lack of distinction between ultraviolet radiation and solar radiation in the books of the present study might confuse children or lead them to the causal connection of ozone depletion with global warming. As Christidou and Koulaidis (1996) stated, *"the specific nature, characteristics, and properties of ultraviolet radiation are fundamental and indispensable elements for an adequate conceptualization of atmospheric ozone"* (p. 16). The lack of these elements from the children's books could constrain children's understanding of the ozone layer and its depletion.

Possible Reasons for the Misrepresentations

The discovery of the recorded misrepresentations is in line with previous studies that described limitations in the representation of various science topics in children's literature (e.g., Sackes et al., 2009; Schussler, 2008; Trundle et al., 2008). Most probably, the books' authors might have neither adequately studied the scientific topic of the ozone layer and its depletion nor consulted scientifically accurate sources of information before writing their stories. Considering that not only children, but also adults have incomplete understanding or alternative ideas about ozone layer depletion (e.g., Boyes et al., 1995; Khalid, 2001), the inaccuracies detected in the texts might reflect the authors' alternative ideas. Also mentioned by Sackes et al. (2009) and Schussler (2008), the limited scientific background of authors can be a source of errors and inaccuracies in the scientific content of children's books. The misrepresentations of ozone might also be attributed to the books' genre. Since the storybooks are not mainly written for the provision of scientific information but for entertainment (Donovan & Smolkin, 2002), elements of fantasy and scenes that cannot take place in real-world situations are

encountered in the story plot. Furthermore, the omission of facts and oversimplifications might stem from the books' intended age group. The books under study were suitable for three years and upwards and, as a result, abstract and complex science concepts about the ozone layer were oversimplified to become to some extent understood by children.

Implications for Classroom Use

Although books under study contain misrepresentations about the nature and role of ozone, they should not be excluded from science or environmental education in primary schools. Primary school teachers should be aware of these misrepresentations to turn trade books into learning opportunities by using several approaches (Sackes et al., 2009). Research indicates that young children tend to perceive children's books as an authoritative source of information (Rice, 2002) and they have difficulty in distinguishing fantasy from reality (Wells & Zeece, 2007) and accurate from inaccurate content (Mayer, 1995; Rice, 2002). Thus, one suggestion that can be made includes pairing the reading of a children's storybook with a scientifically accurate nonfiction book on the same subject. As Trundle et al. (2008) and Owens (2003) argued, children will have the opportunity to compare and contrast the content of the two books and detect the misleading information that contradicts the scientifically accepted view. Teachers could also encourage children to notice elements of fantasy and parts of the story plot that cannot be encountered in the real world. Setting questions, such as "could the wizard really turn the cotton into ozone?", would enable readers to critically think about the scientific content and prevent them from forming alternative ideas. Considering that the concept of the ozone layer is abstract, and children do not directly experience it, the use of scientifically accurate nonfiction resources is also suggested. Videos, simulations, and depictions of the ozone layer could help students to gain an accurate understanding of the nature and role of ozone while reading or listening to fictional stories.

CONCLUSIONS

The present study examined how the ozone layer was portrayed in children's books about ozone layer depletion available in Greece. Children's books analyzed in our study are shown in **Appendix A**. Survey recorded the cognitive elements and information about nature and role of ozone embedded in texts and compared them with scientific consensus view. Errors, oversimplifications, inaccuracies, omissions of facts, and elements of fantasy and magic were identified.

The results highlight concerns about the impact of the recorded misrepresentations on primary school children's learning. Since it is not mandatory for Greek primary school students to receive formal teaching concerning ozone layer and its depletion, it seems possible that they collect information about this issue from children's trade books. Reading or listening to the books of the present study might lead children to the construction of alternative ideas about the position, the distribution, and origin of ozone as well as its role in the Earth's atmosphere and the mechanism preventing UV radiation from reaching the Earth. Comparisons between the misrepresentations of ozone noted in the texts with children's alternative ideas identified by previous studies revealed that some of the children's alternative ideas are also found in children's books. There is the likelihood that children's interaction with the texts will lead to the reinforcement of existing alternative ideas about the ozone layer.

Our analysis of the children's books revealed that collaboration between the publishing companies and the scientific community needs to be encouraged to improve the representation of science concepts and phenomena in children's literature. A scientific committee could review the science content of children's books and provide both authors and publishers with comments and recommendations about the content accuracy, prior to publication. The authors could also consult reliable scientific information resources, before writing their books, to create more accurate content around science topics. More training is also needed to support primary school teachers to critically examine the science content of children's trade books when selecting them for teaching. Identifying the strengths and weaknesses of children's books is crucial for their effective use in classrooms. Given that trade books play an important role in learning, it is of increased importance that stories depict scientific and environmental issues accurately and they are carefully chosen and introduced by teachers to enhance children's understanding of environmental issues.

Limitations and Future Research

The present study has some limitations that should not remain unmentioned. First, it should be noted that the reported children's alternative ideas about the ozone layer reflect the authors' interpretations and assumptions only, which are based on the misrepresentations of stratospheric ozone found in the texts and on previous empirical research on children's ideas and mental models about ozone layer depletion. In future studies, it is vital to examine the impact of the children's books on students' learning about the ozone layer and on their ability to distinguish accurate from inaccurate information embedded in texts. Second, the children's books were analyzed only in terms of content accuracy, while other features that determine content were excluded. Future studies that examine the complexity of the content, such as the depth and breadth of topic coverage, or the appropriate reading level of each book need to be performed for a comprehensive view of the textual content. Third and last, in the present analysis, only children's books in Greek were examined. Extending this study to include children's books written in other languages or published abroad would allow comparisons for content differences.

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APPENDIX A: CHILDREN'S BOOKS ANALYZED IN THIS STUDY

1. Frangouli-Argyri, J. (2011). *O Pol kai I Lara Taksidevoun* [*Paul and Lara travel*]. Psychogios.
2. Iliopoulos, V. (2009). *Paidia se drasi! H ora na sosoume ti gi exei ftasei* [*ECOtales children in action–save the earth*]. Patakis Publications.
3. Michailaki-Arfara, V. (2008). *H aorati ombrela* [*The invisible umbrella*]. Diaplasi.
4. Michalopoulos, N., & Verouli, A. (2008). *O Ai Vasilis fetos einai prasinos* [*This year's Santa Claus is green*]. Agyra.
5. Papadopoulou, E. (2008). *H kyra-fysi kai o kakos rypos* [*The mistress-nature and the evil pollutant*]. Livani Publishing Organization.
6. Papatheodoulou, A. (2008). *O magos tou ozontos* [*The wizard of ozone*]. Minoas Publications.
7. Shomei, Y. (1999). *Tinos einai o aeras?* [*Whose air is it?*]. Sygchronoi Orizontes.
8. Tasakou, T. (2002). *O kokkinos gigantas: Mia istoria tis gis kai tou iliou* [*The red giant: A story of the earth and the sun*]. Kedros.
9. Zarambouka, S. (2008). *Fysika s' agapo* [*Of course I love you*]. Kedros.