

# Misconceptions in Australian Students' Understanding of Ozone Depletion

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## 1. Introduction

Declining levels of stratospheric ozone resulting from anthropogenic source gases is internationally recognized as one of the Earth's most important environmental issues. In the last twenty years, global ozone trends show that concentrations are decreasing by 2-5% per decade in the middle latitudes. The societal concern is that with decreasing concentrations of ozone, the amount of the Sun's ultra-violet (UV) radiation reaching the Earth's surface will increase and potentially damage both human and other biological life.

The goal of this pilot study is to investigate whether misconceptions exist in Australian students' understanding of ozone depletion and the relationship to skin cancer in Australia. Students from year 3 through first year university were questioned about issues related to ozone depletion and skin cancer. A simple experiment is developed to examine whether some student concepts can be altered through the use of visual diagrams. Included in this paper is an update on the current status of ozone depletion over Australia, and the relationship to UV radiation and skin cancer. In addition, a brief review of newspaper articles written about ozone depletion is conducted to explore what possible role the media plays in public misconceptions. Understanding the origin of students' ideas can assist teachers in producing more effective study programs<sup>1</sup> and may be useful in developing a national strategy for teaching environmental issues.

In Australia there is a particular interest in sun related issues because of the population's high incidence of skin cancer. For example, in 1995 approximately 270,000 cases of non-melanocytic skin cancer were diagnosed. This suggests that nearly two in three Australian residents will be treated for some non-melanocytic skin cancer during their lifetime. For the more life-threatening melanoma skin cancer, over 7,000 cases were diagnosed in Australia, with almost 1,000 fatalities reported. It is estimated that the cost of treating skin cancer in Australia is between \$300-500 million per year.<sup>2</sup>

In an attempt to improve the awareness of the dangers of sun related diseases, the government initiated a number of sun awareness campaigns to educate the public. These campaigns have been highly effective in getting across the message of the sun's potential harm. In a survey by the Victorian Anti Cancer Council, almost 80% of respondents had heard the term '*Sun Smart*,' and correctly understood what the phrase meant.<sup>3</sup> Student awareness of the sun and issues related to ozone depletion are also particularly strong. In a recent survey of high school students from Melbourne and Brisbane, the destruction of the ozone layer was identified as the most important environmental issue facing Australia and the

world<sup>4</sup>. However, although public education campaigns about the dangers of extensive sunlight have dramatically improved awareness of sun related diseases, it is unclear how well informed the public is about issues related to ozone depletion and its environmental impact on Australia.

Studies of British and American students show that their understanding of the importance of the ozone layer and the potential of the sun to cause skin cancer are well understood. Not so well understood, however, is their understanding of ozone depletion.<sup>5,6</sup> For example, a study of over 7,000 British students (age 13-14) reveals that only 10% had the correct conceptual model for the relationship between ozone depletion, global warming and UV radiation.<sup>7</sup> Further studies indicate that the models students use to explain ozone depletion and global warming are often intertwined and confused.<sup>8</sup> Boyes and Stanisstreet found that a majority of students who linked ozone depletion and global warming, believed that holes in the ozone layer caused an enhanced greenhouse effect by allowing more solar energy to arrive at the Earth's surface.<sup>9</sup>

The results of these studies suggest that similar misconceptions may also exist in Australian students. In 1995, a survey of the general public found that more than 40% of Australians misidentified the location of the ozone hole as being over Australia rather than Antarctica.<sup>10</sup> A recent study by Fisher suggests that Australian students confuse the relationship between the ozone hole and the greenhouse effect, thus confusing these two environmental issues.<sup>11</sup>

Misconceptions concerning issues such as the environment, are part of a larger field of educational research focused on understanding science misconceptions<sup>12</sup>. One of the main goals of educators is to better understand how the individual constructs their own conceptual frameworks in relation to various science topics<sup>13</sup>. Naturally, a better understanding of students' ideas and how they develop can lead to better instruction methods and potential improvements in the public understanding of science. The aims of this study are focused on identifying student misconceptions about ozone depletion. Further studies are required to thoroughly investigate why these particular misconceptions exist, and to suggest more effective teaching methods.

## **2. Background: ozone, UV radiation and skin cancer**

The destructive potential of ozone depletion prompted swift action by the scientific community to better understand the natural and human processes that influence global ozone distributions. The link between anthropogenic chemicals and the destruction of stratospheric ozone led to the signing of the Montreal Protocol, a political treaty between over 130 nations agreeing to the gradual phase out of a class of chemicals believed to be potentially harmful to the ozone layer. Although there has been tremendous scientific progress in our understanding of stratospheric ozone, there are still large uncertainties in predictions of how the recovery of ozone will eventuate. In particular, the changing atmospheric temperatures associated with 'global warming', along with unanticipated emissions of various ozone depleting gases, will likely delay the recovery of the ozone layer until well into the 21<sup>st</sup> century.

The biological risks associated with an increase in UV radiation due to ozone depletion have been well documented and provided the impetus for the agreement to phase out ozone destroying chemicals. Increases in damage to the eyes, skin and immune system are the

health consequences of higher UV levels. Without the the Montreal Protocol, elevated UV levels could have severely threatened biological life on the Earth. Although the emission scenarios of the Montreal Protocol suggest that global ozone concentrations will return to ‘normal’ levels sometime after the middle of the 21<sup>st</sup> century, there are large uncertainties, and careful monitoring of this environmental issue will need to continue. In addition, it is also important that an accurate history of our first major threat to the global environment, be recorded and understood, so that its lessons can be used in the future.

**2.1. Global ozone trends: now and into the future**

Variations in stratospheric ozone concentrations over any particular location occur naturally due to the day to day variability of atmospheric winds, and seasonally due to the changing solar zenith angle (angle of Sun’s radiation upon the Earth). Ozone in the stratosphere is sustained by a balance between natural production and destruction mechanisms that together produce the naturally varying ozone layer. In the last two decades, additional ozone destruction mechanisms have been identified and linked to emissions of anthropogenic chemicals such as chlorofluorocarbons (CFCs).<sup>14</sup> Once the CFCs reach the upper atmosphere, they are broken up by UV radiation, and release chlorine molecules which can later react and destroy ozone. The increase in global chlorine levels observed in the stratosphere has been linked with the increased use of CFCs.

The formation of the Antarctic ozone hole occurs each spring over latitudes poleward of 60°S, and is the result of a unique combination of meteorology and chemistry that together produce the conditions necessary for the rapid depletion of ozone in the lower stratosphere. This phenomenon is largely restricted to the area over Antarctica, although so- called ‘mini holes’ have been identified over the Arctic latitudes. During the breakup of the ozone hole in late spring, large areas of ozone depleted air occasionally pass over the southern tip of South America. However, the occurrence of low ozone air over Australia is rare because of prevailing meteorological conditions that normally shield Australia from Antarctica’s low ozone air.

Estimates of ozone trends over various Australian cities are shown in Table 1. Over the last 20 years ozone has declined by at most 2-3 percent per decade over southern Australia.<sup>15</sup> At lower latitudes, the trends are generally smaller or in the case of Northern Australia (e.g. Cairns and Darwin), the trends are small and not statistically significant. Therefore, it is only in Australia’s southern latitudes where negative trends of two to three percent per decade are found.

<b>City</b>	<b>Latitude</b>	<b>Trend (%/decade)</b>
Brisbane	27.5°S	-1.8
Perth	32.0°S	-1.7
Melbourne	38.0°S	-2.5

**Table 1. Trends in total ozone estimated from individual ground based stations compiled from 1979 through 1997.**

Computer model predictions of future ozone concentrations suggest that ozone will return to pre 1970’s levels by sometime after 2050, although large uncertainties still exist.

Recent observations show that trends in global chlorine have leveled off and are now declining as a result of the Montreal Protocol. How fast chlorine levels will decline is hard to estimate due to uncertainties in emission of CFCs and other ozone depleting gases. In addition to these uncertainties, scientists are also concerned about how changing temperatures in the lower atmosphere, associated with global warming, may affect upper atmosphere temperatures and thus ozone levels. Although these questions make accurate predictions of future ozone levels difficult, the promise of declining chlorine levels should allow ozone levels to slowly recover through the 21<sup>st</sup> century.

## ***2.2. UV radiation and skin cancer***

Global trends in UV radiation have historically been difficult to obtain because of sensitivity and calibration issues related to the UV measuring instruments, and because UV radiation is significantly affected by cloud cover and aerosol amount. Recent satellite and ground based estimates of global UV trends have been published, and these generally show that UV levels are increasing throughout the globe. Over the lower latitudes (30°N – 30°S), which includes most of the Australian continent, however, statistically significant trends have not been obtained. In the more southern latitudes (35°S – 50°S), including southern Australia and Tasmania, a trend of nearly +3.5 percent per decade has been identified.<sup>16</sup> Regardless of the observed trends, the relationship between ozone and UV is well understood. Simply put, if ozone concentrations are reduced, then more UV radiation is expected to reach the lower atmosphere. Whether changes in the optical properties of the troposphere (i.e. more or less clouds) occur as a result of changes to the climate is at present too difficult to determine. However in any case, UV levels over Australia are expected to rise as ozone levels fall.

While the relationship between ozone and UV levels seems relatively straightforward, the connection between ozone, UV and skin cancer is more complicated. Skin damage by UV radiation is largely dependent on exposure levels. It is recognized that human behavior can have as great or greater influence on exposure levels as changes in ozone concentrations.<sup>17</sup> Although modeling studies and observations suggest that decreases in ozone concentrations will produce higher levels of UV, this is clearly not the *major* cause of Australia's high rate of skin cancer. More important contributors to Australia's high skin cancer rate include a fair skinned population living in a subtropical climate, and lifestyle and social attitudes. It may be that because of Australia's geographic proximity to the Antarctic ozone hole, and the resulting media attention the ozone hole receives each year, that many Australians feel a particularly strong connection between ozone depletion and high skin cancer rates. Scientific evidence, however, suggest that skin cancer is related to prolonged exposure over many years. Sufferers of skin cancer today should more likely blame their affliction on skin type and sun exposure during their youth than any changes in ozone distributions over the last twenty years<sup>18</sup>. Therefore it is safe to say that even without ozone depletion, Australia would still have a very high rate of skin cancer.

## **3. Questionnaires and results**

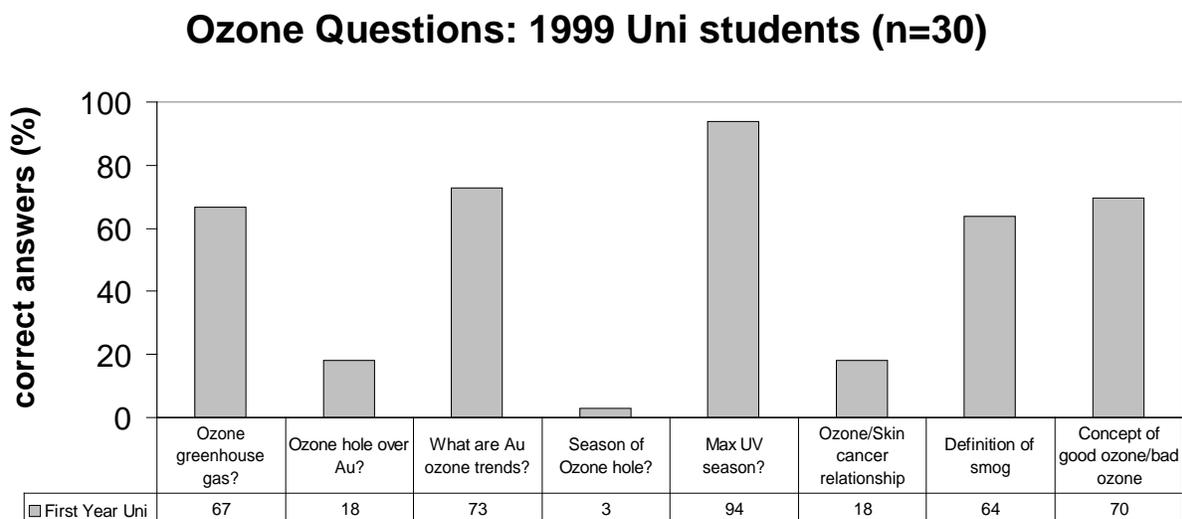
Two populations were surveyed in 1999 to investigate the prevalence of certain ozone misconceptions in the Australia student community. Although the survey sample sizes are relatively small, and only restricted to a region near Melbourne, Victoria, the outcomes of this pilot study may serve as indicators of national trends.

In the initial survey (hereafter referred to as survey 1), thirty university students enrolled in a first year general atmospheric science course, intended for science majors, were questioned about issues related to ozone depletion. In the second survey (hereafter referred to as survey 2), over 800 students filled out ozone questionnaires during *The Great Australian Science Show* in Melbourne, Victoria. Students ranged from year 1 through 12, although the majority of students were in years 3-10. This survey contained four multiple-choice questions.

In both surveys, the general questions focused on two misconceptions identified in an earlier informal student survey conducted by the author in 1998. The first misconception is that the ozone hole resides over Australia, and the second is that ozone depletion is the major cause of Australia's high rate of skin cancer. Although there are other areas where students' understanding may be confused, such as the relationship between ozone depletion and global warming, the focus of this study is centered on the two above mentioned misconceptions.

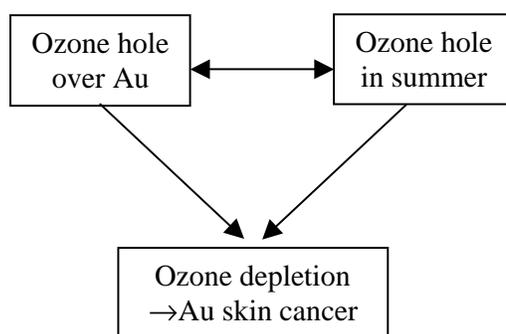
### 3.1. University Survey

The results of the survey of first year university students are shown in Figure 1. A majority of the students correctly identified both the season when UV radiation is at its maximum and the magnitude of ozone trends over Australia. However, over 80% of the students incorrectly identified the ozone hole as being over Australia and 97% incorrectly assumed the ozone hole occurs during the summertime. In addition, over 80% blamed ozone depletion for Australia's high rate of skin cancer.



**Figure 1. Results from the survey of first year university students enrolled in an introductory atmospheric science subject. Numbers indicate the percentage of students who answered the particular question correctly. The survey questioned 30 students.**

While the size of this survey is small, the results indicate the presence of student misconceptions about ozone depletion and how it relates to Australia. Examination of the poorly answered questions leads to the following argument. If students believe that the ozone hole is over Australia, and that the ozone hole occurs during summer, a time when issues of sun safety and skin cancer are heightened, then it is plausible that students may link ozone depletion and the ozone hole with Australia's high skin cancer rates. A concept map for this relationship is given in Figure 2. The identified misconceptions, a) the ozone hole is over Australia and b) the ozone hole occurs during summer, may be combined to explain why students believe that Australia's high rate of skin cancer is due to the ozone hole. Although extensive study would be required to confirm the model students hold, it is plausible that the connection between the location and time of the ozone hole and Australia's high rate of skin cancer has been made.



**Figure 2. A concept map showing how some students relate ozone depletion to Australia's high skin cancer rates. The misconceptions, identified as the ozone hole residing over Australia, and the ozone hole occurring during the summer, together support the notion that ozone depletion is responsible for Australia's high rate of skin cancer.**

### *3.2. Year 1-12 survey*

The second survey questioned students in primary and secondary schools about ozone issues to determine whether similar misconceptions also exist in younger students. In this study, a simple test was designed to explore how easily student held misconceptions could be altered.

The students were divided into two groups. Both student groups were given identical questions, but students in Group 2 were also encouraged to look at some prepared ozone diagrams before completing their answers. These students were also given some assistance in understanding the diagrams. The diagrams included the Southern Hemisphere distribution of total ozone during the spring. The diagrams were designed to highlight the location of the ozone hole, and the relative distance from the ozone hole to Australia.

The results of the two group surveys are shown in Table 2. In Group 1, while most students had a reasonable idea of the spatial and temporal distribution of UV levels over

Australia, in general, students again had a poor understanding of the ozone hole location and the relationship between ozone depletion and Australia's high rate of skin cancer. Nearly 70% of the students incorrectly believe that the ozone hole is over Australia, and almost 80% incorrectly believe that ozone depletion is the major cause of Australia's high skin cancer rates. It again seems reasonable to assume that similar to the university students, these younger students also seem favour the sequence of concepts as shown in Figure 2.

<u>Misconception</u>	Percent who believe	
	<u>Group 1</u>	<u>Group 2</u>
O <sub>3</sub> hole over Australia	70%	24%
O <sub>3</sub> depletion→Au skin cancer	79%	61%

**Table 2. Results of the primary and secondary student survey showing percent who believe a particular misconception. The size of Group 1 and Group 2 are 346 and 497 respectively.**

In Group 2 there is a significant improvement in the number of students who correctly answered the ozone questions. For the notion of the ozone hole existing over Australia, 76% of students correctly answered this question, compared with 30% in Group 1. This improvement can be directly attributed to the diagram of the ozone hole shown to the students. After students were encouraged to identify and locate the ozone hole, most became aware that the ozone hole does not reside over Australia. However, in many cases it was a surprise to students, and often the accompanying parents and teachers, to discover that the ozone hole is not over Australia.

Students in Group 2 show some improvements in their responses to the question concerning the relationship between ozone depletion and skin cancer in Australia. In Group 1, where only 20% of the students correctly answered the ozone depletion/skin cancer question, in Group 2, almost 40% correctly answer this question. This suggests that the concepts students may hold, as illustrated in Figure 2, may be altered by challenging one of the existing misconceptions. When students discovered that the ozone hole is not over Australia, some of them at least may have begun to question the relationship between ozone depletion and Australian skin cancer rates. While this simple experiment does not necessarily confirm whether student understanding improved, it does reinforce the notion that identifying student misconceptions can be important for developing effective teaching strategies. This survey also illustrates how changing student misconceptions is inherently challenging. While Group 2 almost doubled their number of correct answers for the ozone depletion/skin cancer relationship, still over 60% of respondents answered incorrectly.

#### **4. Media coverage on ozone depletion**

Much of what the public understands about the current state of the environment comes from the media. In a poll conducted by the Australian Bureau of Statistics, 85% of respondents indicated that most of their information about the environment came from newspaper, television or radio.<sup>19</sup> Inaccuracies in the reporting of these environmental issues

may confuse issues that already are complex and misunderstood. Thus it is possible that some of the public confusion surrounding global issues such as ozone depletion and global warming may stem from the media. To evaluate the potential role the media plays in the development of student (and public) misconceptions, newspaper articles containing the keyword “ozone” were compiled from the Melbourne Age and Sydney Morning Herald for the years 1993-1999. The articles were examined in relation to their accuracy when describing the location of the ozone hole, the level of ozone depletion over Australia, and the possible connection between ozone depletion and skin cancer.

It was found that articles written specifically about the ozone hole or ozone depletion were in general factual, although their description of the responsible mechanisms were often vague. However, more general environmental articles, or articles not specifically focused on ozone depletion, often contained misconceptions or inaccuracies. These statements occurred with surprising frequency and are likely to compound the confusion of the general reader.

Examples of some of the statements that appeared in newspaper articles include:

‘December 1987: The hole in the earth’s ozone layer moves over southern Australia for about a month.’ -The Age, 2 June 1999,

‘...said Australians were at particular risk of exposure to UV radiation because the hole in the ozone layer was above Australia.’ -The Age, 3 October 1998,

‘As the ozone hole over the Antarctic gets larger and overlaps Australia, more ultraviolet rays from the sun are able to damage the pale skin of cats and dogs.’ -The Age, 26 January 1997,

‘Pack the 15+ sunblock. The hole in the ozone layer across Tasmania necessitates the wearing of sunscreen even on cloudy days’ -The Age, 21 March 1993,

‘The effect of a large hole would be a decrease in ozone levels in southern Australia’ -Sydney Morning Herald, 7 Oct 1993,

‘Ozone hole growing, on the way, NZ warns... Less than 12 months after it first crept over inhabited parts of the Earth, the ozone hole is spreading towards Australia and might reach southern states as soon as next month, New Zealand scientists warned yesterday.’ -The Age, 24 September 1993.

In the seven years of articles compiled from the Melbourne Age, there were on average three to four articles a year about the current state of the ozone layer, and a few short statements describing the current state of the Antarctic ozone hole during spring. Most of these articles were accurate and a reasonable description of the science related to ozone depletion. The more common situation where misinformation occurred was found in general environmental articles or general topic articles. For example, of the twenty-five environmental or general interest articles that mentioned ‘ozone’, over fifteen of them contained inaccuracies or misinformation about ozone depletion.

It is difficult to estimate what influence newspaper misstatements and inaccuracies as illustrated above have on public understanding, or how prevalent these are in television and

radio. What it does reflect is that some of the general misconceptions and misunderstandings that exist in general public also exist in the media. It is also clear that these misstatements do not help public understanding of environmental issues.

## 5. Discussion

Although it appears that many Australian students may be incorrectly blaming ozone depletion for their skin cancer concerns, their understanding of various sun protection strategies is very good, and a positive social lifestyle choice. A relevant question is then, would teaching the correct model undermine or confuse the work of programs such as *Sun Smart*? Certainly, this is a point of consideration, and environmental educators must consider these repercussions. It seems clear that educating students with the correct model serves not only the individual, but the public as well. For example, students with a clear understanding of the relationship between ozone depletion and their environment realize that even if ozone values again reach pre 1970's values, as predicted sometime well into the 21<sup>st</sup> century, their susceptibility to sun damage remains high if they choose to live in a high sun dosage environment like Australia. In addition, it is clear that students will have to face other environmental challenges in the coming decades. If the lessons and difficulties of ozone depletion are communicated effectively to the youth today, then tomorrow's public should be better equipped to handle the demands of future environmental concerns.

While the teaching of ozone depletion in schools poses a number of difficulties, there are also great rewards. One difficulty that students face is that global issues, such as ozone depletion and global warming, are generally more difficult to perceive than local issues.<sup>20</sup> For example, the pollution of beaches is a problem that children can see and easily understand. The question of who is harmed, and what action should be taken to remedy the situation is also fairly clear. Global issues, on the other hand, generally have more levels of complexity associated with them and often require years to develop adequate solution strategies. However, global issues also offer excellent teaching opportunities, and in some cases, these issues have important health consequences that are relevant to the survival of our population. Understanding the relationship between what an individual does and how it can influence others both locally and globally may illustrate to students their relative position in the world. Ozone depletion is also a relevant interdisciplinary science issue that incorporates fundamental topics in biology, chemistry, meteorology and physics. In addition, the teaching of ozone depletion can combine science topics with facets related to politics, social culture and economics.<sup>21</sup> For example, in the case of ozone depletion and skin cancer in Australia, teachers can explain how the indigenous populations of Australia have relatively low rates of skin cancer, while most of the European migrants, originally from higher latitudes environments, have higher rates of skin cancer. The ramifications of history, culture, evolution and migration can all be discussed under this global environmental issue.

Another potential difficulty in teaching environmental issues such as ozone depletion and global warming is that teachers may feel uncomfortable presenting these relatively technical subjects. Discussions with teachers during the student survey indicate that these topics were often found confusing and difficult to explain. This seems consistent with the media survey, where facts related to ozone depletion are often confused or incorrect. Teachers require a variety of resources and information in a language that is accessible to the general public. Material based fact sheets, diagrams and activities that are designed to generate interest and understanding are clearly needed for such topics. It seems that encouraging scientific

agencies to better communicate with teachers and students through the dissemination of useable materials would be helpful. If teachers don't feel comfortable in their own understanding of these topics, their students may never have the opportunity to explore these subjects.

## **6. Conclusions**

This pilot study has identified two misconceptions Australian students have about ozone depletion. First, that a large portion of the ozone hole is over Australia, and second, that Australia's high rate of skin cancer is mainly due to ozone depletion. In comparison to the studies in Britain and the United States, the work here suggests that slightly different misconceptions exist in Australian students, seemingly because of Australia's relative proximity to the Antarctic ozone hole. It is also found that by challenging students' misconceptions about the location of the ozone hole, through the use of visual illustrations, students improved their ability to correctly identify that Australia is not under the ozone hole. Improvements in their understanding of the relationship between ozone depletion and Australia's high rate of skin cancer were more difficult to achieve. However it does appear that some students began to question their own explanation for Australia's high skin cancer rates after becoming aware of the correct location of the ozone hole.

The origin of student misconceptions has also been briefly explored. The general level of misunderstanding concerning ozone depletion that exists in the general public<sup>22</sup> is also found in various newspaper articles. If the general public, including teachers and parents, are confused or have misconceptions about ozone depletion, then it is not surprising that many students also hold these views. However, the development of these ideas in the first place is still unclear and will require further study into science misconceptions in the Australian public.

It is argued that, while the effective teaching of global environmental issues is inherently challenging, especially when the public is also largely misinformed, it is important that children be exposed to the correct environmental models and be given a chance to explore the ramifications of changes to their environment. The teaching of issues such as ozone depletion also offers an excellent opportunity to explore the interdisciplinary nature of science, in addition to topics in politics and economics. However, teachers need to be comfortable with the underlying science beforehand, and thus require supporting materials to improve their own understanding. In addition, the development of teaching materials including activities, diagrams and other resources would make the teaching of such subjects more accessible and enjoyable. The development of effective teaching materials, however, requires an understanding of students' misconceptions and the origin of students' ideas. From the results of this pilot study, it seems clear that more comprehensive studies should be undertaken in Australia to identify and understand the models students use to explain global environmental issues such as ozone depletion and global warming. This information is clearly needed by educators before they can develop effective strategies for teaching environmental issues and before improvements in the public understanding of these issues can be expected.

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