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Is the Ozone Hole Over Your Classroom?

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FEATURE ARTICLE

Is the ozone hole over your classroom?

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Biographical Resume

Eugene Cordero is a researcher and lecturer at Monash University. His areas of research include stratospheric dynamics and ozone depletion. Recently, Eugene has become interested in students' perceptions of environmental issues such as ozone depletion and global warming. Eugene completed his Ph.D. at University of California, Davis in 1995, after which he worked at NASA Goddard Space Flight Center before coming to Monash University.

ABSTRACT

First year university science students are surveyed about their understanding of the ozone layer, ozone depletion and the effect of ozone depletion on Australia. Although students seem to understand the basic function of the ozone layer, over 65% of students incorrectly believe that the ozone hole is over Australia, and over 90% of students incorrectly believe that the ozone hole is present during the summer. Together these ideas seem to explain why nearly 75% of students blame the ozone hole for Australia's high rate of skin cancer. Survey results also indicate that students seem confused about global warming, and the connection with ozone depletion. Conclusions from this study suggest that better teaching resources for environmental issues such as ozone depletion and global warming are needed before improvements in students' understanding can be expected.

INTRODUCTION

The depletion of the ozone layer is recognised as one of the Earth's most important environmental issues. The realisation that anthropogenic chemicals such as chlorofluorocarbons (CFCs) could potentially destroy the Earth's protective shield, known as the ozone layer, prompted swift action internationally to reduce these ozone depleting chemicals. The signing of the Montreal Protocol and further amendments aim to restore ozone levels to their pre 1970s distributions by sometime in the middle of the 21st century (World Meteorological Organization, 1999).

Australia is a country with a particular interest in sun-related issues because of the population's high incidence of skin cancer (Australian Institute of Health and Welfare, 1998). Campaigns about sun safety have been highly effective in getting across the message about the sun's potential harm (Dobbinson and Borland, 1998). Although the terms 'ozone depletion' and 'ozone hole' are also well recognised by the Australian public, it is not clear that the public has a realistic understanding of how ozone depletion influences Australia. For example, 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 (Bureau of Industry Economics, 1995).

Based on the prevalence of misconceptions in the general public, it is not surprising that students may have similar ideas. Studies of British and American students found that only 10% held the correct conceptual model for the relationship between ozone depletion, global warming and UV radiation (Boyes and Stanisstreet, 1997). Similar findings were found in Australian students, who also appear to confuse the relationship between the ozone hole and the greenhouse effect (Fisher, 1998). However, Australian students also have slightly different ideas about the relationship between ozone depletion and Australia. For example, a recent pilot study of Australian students (Year 5 through Year 11) found that over 75% believed that the ozone hole is over Australia, and that ozone depletion is largely responsible for Australia's high rate of skin cancer (Cordero, 2000). These ideas may be in part due to Australia's relative proximity to the Antarctic ozone hole, and the country's high incidence of skin cancer.

The goal of this paper is to further investigate student understanding of concepts related to ozone depletion using questionnaires. The study group will be first year university science students, a population that may serve as an indicator

for how well secondary school students understand this environmental issue. The motivation for better understanding student ideas is that prior identification and awareness of student misconceptions can be useful in assisting teachers in producing more effective study programs (Fisher, 1998). Before the sections describing the student questionnaires and results, an update on the current status of ozone depletion over Australia, and the relationship between ozone depletion and skin cancer, is provided.

UPDATE ON OZONE DEPLETION AND THE RELATIONSHIP TO SKIN CANCER

Decreasing levels of stratospheric ozone, including the Antarctic ozone hole, have been primarily linked with the production of anthropogenic chemicals such as CFCs (WMO 1999). A gradual phase-out of these chemicals has been initiated by the signing of the Montreal Protocol (and further amendments), an international agreement that aims to restore ozone levels to their pre-1970s level.

The Antarctic ozone hole is recognized as one of the most striking indicators of ozone depletion. The recipe for producing an ozone hole can be compared to that of baking a cake. During winter, the necessary ingredients for ozone depletion are prepared in the high latitude Southern Hemisphere, just like putting in the sugar, eggs and self-raising flour. In the spring, the returning sunlight initiates the chemical reactions that destroy ozone, just as the heat of an oven causes the dough to rise. The location of the ozone hole, as shown in Figure 1, is generally confined to the latitudes over Antarctica, although there are occasions when the ozone hole can move over lower latitudes locations such as South America. However, due to prevailing meteorological conditions, the ozone hole has never passed over the Australian continent.

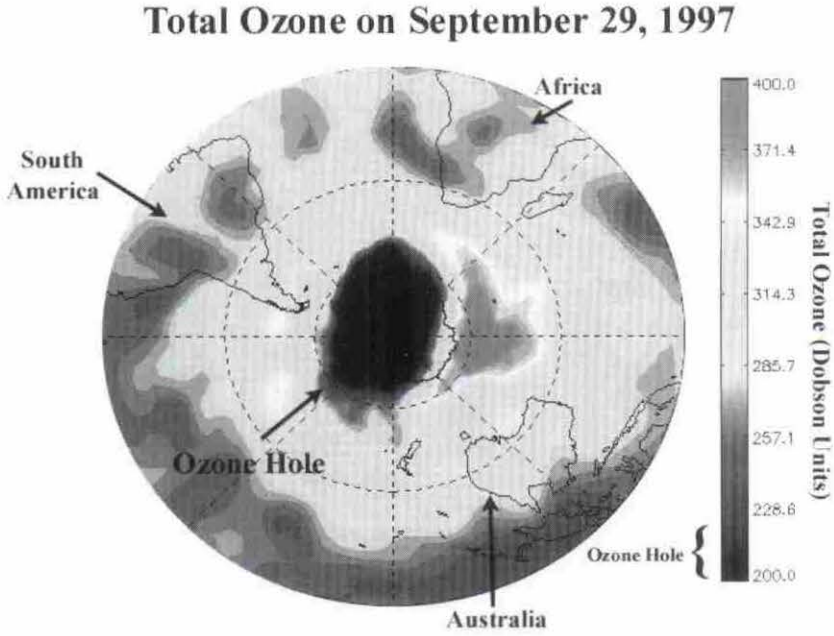

Figure 1. Southern Hemisphere view of total ozone on September 29, 1997 as calculated using the Monash University Transport Model. Large values of total ozone are indicated in the lighter tones, while the low values of ozone are indicated by the darker tones and black. Note that the ozone hole is defined as a region where total ozone is below 220 Dobson units.

Although the ozone hole is generally confined to the high southern latitudes, decreasing levels of ozone have been observed throughout the middle latitudes (Northern and Southern hemisphere), while in the Tropics (20N – 20S) ozone trends are essentially zero. For example, ozone levels over Melbourne and Brisbane have been decreasing at 2.5 and 1.7 percent per decade, respectively, while there are no trends over Cairns and Darwin (trend not statistically significant). Therefore, it is only in Australia's southern latitudes where negative trends of two to three percent per decade have been recorded.

The estimates of future ozone levels, using emission scenarios of CFC and halons as outlined by the Montreal Protocol, predict that ozone will return to pre 1970s levels by sometime after 2050, although large uncertainties still exist. Recent observations show that trends in global chlorine, which is ultimately responsible for ozone depletion, have leveled off and are now declining in part due to 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. These questions make accurate predictions of future ozone levels difficult. Even so, the promise of declining chlorine levels should

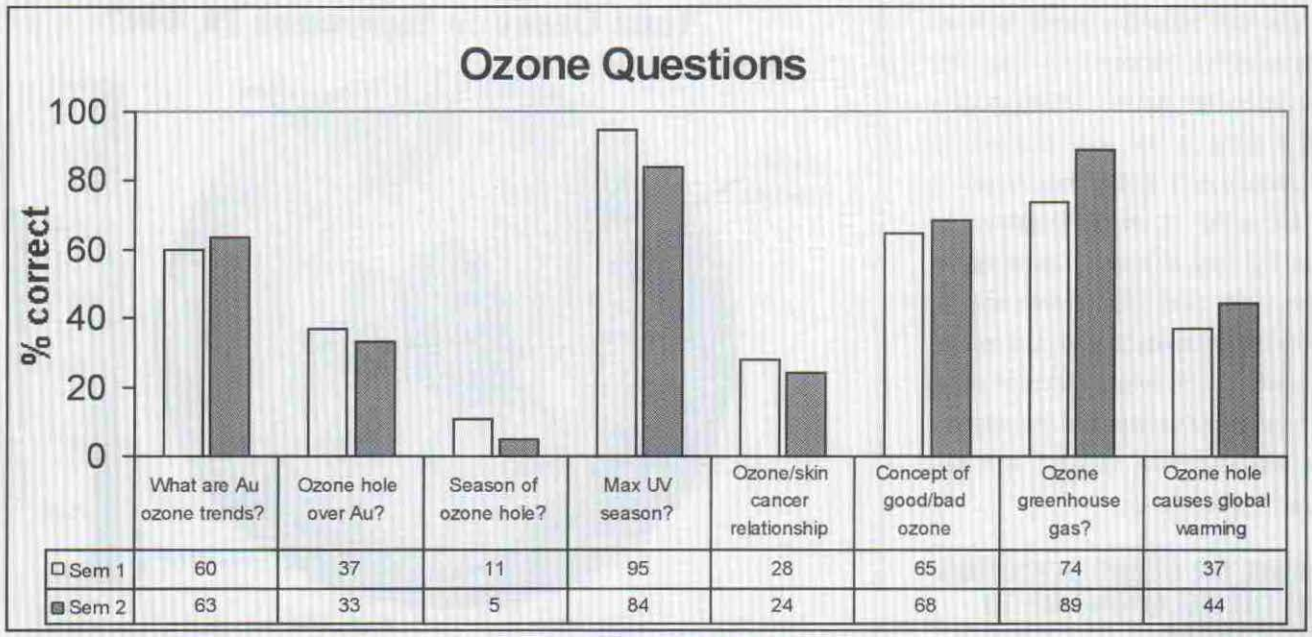

Figure 2. Results from the survey of first year university students enrolled in an introductory atmospheric science subject in semesters 1 and 2. Numbers indicate the percentage of students who answered the particular question correctly. The survey sample size is 120 students.

allow ozone levels to slowly recover through the 21st century.

While decreasing ozone levels alone would produce higher levels of ultraviolet radiation (UV), the relationship between ozone depletion and skin cancer is more complicated. Damage to the skin is related to a number of factors including exposure levels and skin type. Therefore human behaviour can have as great or greater influence on exposure levels as changes in ozone concentrations. The people of Australia are a prime example. Although it is likely that over the last 20 years, UV levels have risen over Australia due to decreasing ozone levels, this is clearly not the major cause of Australia's high rate of skin cancer. A more important factor appears to be the prevalence of a fair skinned population living in a high sunlight environment. Evidence that Australia is a natural high sunlight environment can be found by looking at the skin colour of the indigenous population, which has had thousands of years to adapt. Therefore, it is not surprising that a migrating population essentially from Britain and Europe would be at risk to sun-related illnesses. In addition, scientific evidence now suggests that many of today's cases of skin cancer can be traced back to prolonged exposure over many years (Armstrong, 1997). Therefore, today's sufferers of skin cancer should blame their skin type and/or sun exposure during their youth rather than blame any changes in ozone distribution over the last 20 years. Having said this, it should be acknowledged that today's youth is at higher risk to sun-related illnesses compared to 20 years ago, due to today's higher UV levels. This argument, therefore, is not intended to diminish the real and important concerns about ozone depletion, rather to put in perspective the impact ozone depletion has had on Australia's population.

OZONE QUESTIONNAIRES

Initial survey

Over the course of a year, 120 first year university science students enrolled in an introductory atmospheric science subject were surveyed at the beginning of the semester. The students were questioned about issues related to ozone depletion and global warming. In addition, one student group was also asked more detailed questions about their ideas on ozone depletion in order to investigate the interrelationship between students' various ideas and concepts. Although the survey sample sizes are relatively small, and only restricted to a population near Melbourne, the outcomes of this pilot study may serve as indicators of national trends.

Figure 2 is a summary of the results from the initial questionnaire. A large majority of the students correctly identified summer as the season when UV radiation

is at its maximum. Students also did fairly well on questions related to the concept of good and bad ozone and whether ozone is also a greenhouse gas. However, students did not do so well on questions relating to the ozone hole. Over 60% of the students incorrectly identified the ozone hole as over Australia, and over 90% of the students believed that the ozone hole is present during summer, instead of spring. In addition, students also believed that ozone depletion is largely responsible for Australia's high rate of skin cancer, and that the ozone hole is responsible for global warming.

These results, which agree with previous surveys of pre-university students, suggest that Australian students have particular misconceptions about ozone. Some of these misconceptions appear to be interrelated, and were further studied using a more detailed questionnaire.

Detailed questionnaire

A second questionnaire was given to the Semester 2 student group (65 students) with the aim of further probing student ideas about the ozone hole and skin cancer, and the relationship between ozone depletion and global warming. Students were given a variety of statements which they would support or refute, using their appropriate level of confidence (eg a) I am sure this is correct; b) I think this is correct; c) I don't know; d) I don't think this is correct and e) I am sure this is incorrect). In this way, the support of different models of understanding could be identified.

Responses from some of the questions are shown in Figure 3. Over 50% of the students incorrectly believed there was a relationship between ozone depletion and Australia's high rate of skin cancer, while a further 27% didn't know. Students were more confident that during summer UV radiation is high over Australia because of the ozone hole. Of these students, over 50% supported the statement that the ozone hole is over Antarctica, but grows and moves over Australia, while 40% believed the ozone hole is always over Australia, but gets larger during summer.

From these results there appears to be a relationship between student concepts about UV radiation, the ozone hole and skin cancer, as outlined in the concept map in Figure 4. The primary ozone misconceptions, *'ozone hole over Au'* and *'ozone hole occurs during summer'* seem to link up with the correct concept that maximum UV occurs in summer. Together, these misconceptions lead to a further misconception about the connection between ozone depletion and Australia's high rate of skin cancer.

A further point is made about the relationship between ozone depletion and global warming. Over 40% of students

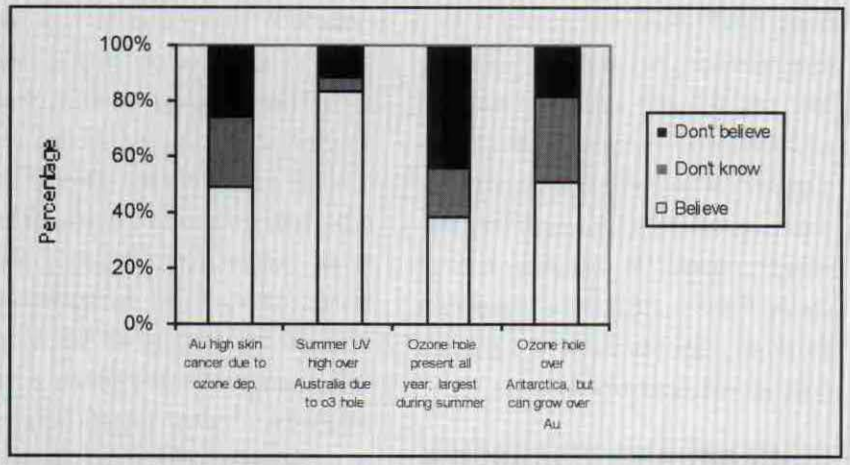

Figure 3. Percentage of students who believe, don't know, or don't believe in particular statement.

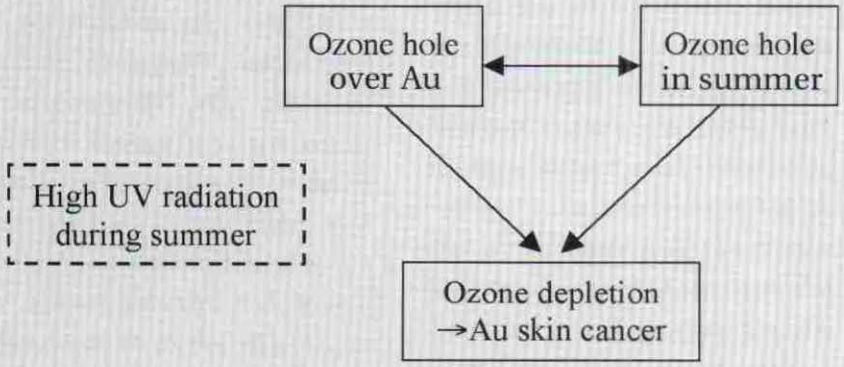

Figure 4. A concept map showing how some students relate ozone depletion to Australia's high skin cancer rates. The misconceptions, identified as the ozone hole residing over Australia, and the ozone hole occurring during the summer, together with the correct concept that UV radiation is maximum during summer all support the notion that ozone depletion is responsible for Australia's high rate of skin cancer.

believed that holes in the ozone layer were responsible for global warming, while over 60% believed that automobile pollution was responsible for ozone depletion. This suggests that the confusion between these two environmental issues is not only with younger students as identified in other studies (Francis, 1993; Potts, Stanisstreet and Boyes, 1995; Francis, 1998), but is also prevalent with university students.

SUMMARY AND DISCUSSION

Questionnaires given to first year university science students were used to explore student misconceptions about ozone depletion. The results indicate that while students seem to have a good understanding of general ozone concepts, they poorly understand the ozone hole and how it influences Australia. In particular, a majority of students incorrectly believe a) the ozone hole exists over Australia b) the ozone hole is largest during summer c) ozone depletion is responsible for Australia's high rate of skin cancer and d) a direct relationship exists between ozone depletion and global warming. The first three misconceptions appear to be interrelated, and are supported by the correct student concepts that summer has the highest UV levels of radiation and that Australia has a high rate of skin cancer. Earlier studies of pre-university students (primary and secondary school) show that similar misconceptions exist, thus it does not appear that students are advancing their understanding of environmental issues such as ozone depletion and global warming much through secondary school.

While many Australian students know when to *slip, slop slap*, slogans of the successful Sun Smart campaign, they also seem to blame ozone depletion for their skin cancer concerns. Although these misconceptions may serve to help modify social behavior, in particular protecting oneself from the sun, it is the role of educational institutions to present the correct scientific models of understanding. It also appears that the lessons of environmental issues, such as ozone depletion, are not being communicated to students. For example, the message of the Montreal Protocol and further amendments, although not yet confirmed as a success story, serves as an excellent illustration that indeed something can be done to protect the environment. However, in the above questionnaire, almost 80% of the students felt that during the last decade the ozone hole had been growing rapidly, which is not true (WMO 1999). Putting resources into the teaching of environmental issues would therefore seem a good approach, especially since many of today's youth rank environmental issues high in their list of concerns (Connell, Fien, Sykes and Yencken, 1998). Explaining the lessons we have learned to today's students should provide an understanding and capacity for the potentially difficult decisions individuals will need to make with regards to future environmental issues.

However, one of the difficulties in teaching environmental topics such as ozone depletion and global warming is a lack of good teaching resources. Because these topics are current and constantly changing, textbooks may be out of date, and thus teachers could feel uncomfortable or ill-prepared to teach these subjects. In the development of effective teaching materials, it seems important to identify and understand the existing concepts students have about these issues. From the results of this and previous studies, it seems clear that a more comprehensive effort in Australia should be undertaken to better understand students' ideas about environmental issues such as ozone depletion and global warming, with the intent of developing more effective teaching materials. A search for support for such a project is currently underway. If readers are interested in further information, have suggestions, or would like information about obtaining teaching materials, please contact the author.

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