Plus ça change, plus c'est la même chose? School Students' Ideas about the "Greenhouse Effect" a Decade On

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Abstract

This report describes a survey of the ideas and feelings of UK students about global warming, and comparisons are made to those from a similar closed-form questionnaire which had been used 9 years previously. Comparison of the responses of the two cohorts suggests that the current generation of students have fewer scientific ideas about the greenhouse effect, but also hold fewer misconceptions. Those students who reported using television as a source of information showed greater knowledge about global warming, but did not hold fewer misconceptions, whereas students who reported learning most about the greenhouse effect from school did show fewer misconceptions. It is suggested that this may indicate limitations of learning from television or other electronic sources such as the Internet, in that pre-existing or newly-generated misconceptions cannot be detected, or therefore challenged.

Résumé

Ce rapport décrit un recensement des idées et des sentiments des étudiants de la Grande-Bretagne à l'égard du réchauffement planétaire et établit des comparaisons avec les idées et les sentiments exprimés par d'autres étudiants en réponse à un questionnaire semblable utilisé dix ans auparavant. La comparaison des réponses des deux groupes suggère que la génération actuelle d'étudiants ont moins d'idées scientifiques à propos de l'effet de serre, mais ont aussi moins d'idées fausses. Ceux qui ont recours à la télévision comme source d'information démontrent une plus grande connaissance du réchauffement planétaire, mais n'en ont pas moins des opinions erronées. Par ailleurs, les jeunes qui prétendent avoir appris le plus au sujet de l'effet de serre à l'école en avaient moins. Cette étude révèle

qu'il y a peut-être des limites à apprendre de la télévision ou d'autres sources électroniques comme Internet, parce qu'il impossible de déceler et, par conséquent, de contester les mauvaises interprétations préexistantes ou nouvelles.

The best time to plant a tree is twenty years ago;
the next best time is now.

(Native American Proverb)

Several years ago, in a publication about school students' ideas about the "greenhouse effect," it was prudent to refer to the phenomenon of "global warming"[1] in tentative terms (Boyes & Stanisstreet, 1993). At that time, although there was international concern about global warming (IPC, 1991), and although the magnitude of its potential consequences was appreciated by some (Tickell, 1991), the scientific case for the existence of global warming was still considered, in some quarters at least, as unproven (Gribbon, 1990; Mason, 1992). During that period, a study of school students' ideas showed that although certain facts about global warming were well known by school students, their knowledge of other areas was less secure (Boyes & Stanisstreet, 1993). For example, although students were familiar with some of the causes of global warming, such as a raised concentration of atmospheric carbon dioxide, they were less cognisant of other causes, such as ground-level ozone. Similarly, certain actions which would reduce global warming, such as restricting car use, were well known, whereas others, such as using nuclear-generation of electricity in place of coal- or oil-fired generation of electricity, were less well known. When ideas about the possible consequences of global warming were examined, it was clear that most of the students knew about the possibility of climate change, whereas fewer appreciated that such changes could affect the distribution of crop pests. In addition, certain widely-held misconceptions were identified. Some, such as the ideas that global warming would cause an increase in the incidence of skin cancer and that global warming was a result of ozone layer "holes," were later identified as apparently being due to a general confusion between global warming and ozone layer depletion (Boyes & Stanisstreet, 1997, 1998; Fisher, 1998). Others, such as the idea that global warming could be reduced if vehicles used lead-free gasoline, probably originated in a more general conflation of ideas, perhaps originating in a imprecise use of language—that all pollutants cause "pollution," and that "pollution" causes a range of deleterious effects (Boyes & Stanisstreet, 1996; Stanisstreet & Boyes, 1996).

More recently, scientific accumulated evidence indicates that global warming is indeed more certain, and that this is due to an exacerbation of the greenhouse effect by anthropogenic atmospheric pollutants. More has been learned about the complex physico-chemical mechanisms of the greenhouse effect and this, together with the availability of increased computing power, has enabled increasingly sophisticated modeling of the phenomenon. This, in turn, has allowed predictions to be made of the time-scale of the increase in global warming. Furthermore, the results of various scenarios in which greenhouse gas emissions are reduced to different degrees can be predicted. It is also becoming clearer that there will be a range of physical, climatological, and biological consequences of an increase in global temperature (Environmental Defense Network, 1999), although the socio-economic ramifications of these are difficult to anticipate because of their complexity and dependence on human factors.

Reduction of global warming, and compensation for or avoidance of its effects, are likely to prove costly in individual terms and unpopular in political terms, and it will prove easier to effect the necessary steps if the public is aware of the need for action and penalties of inaction. In the light of the increased certainty that global warming is, in fact, occurring and the improved understanding by specialists of the details of its mechanisms and consequences, one might anticipate—indeed hope—that the public is now better informed than previously, when the situation was less certain. The aim of the present study, therefore, was to repeat a survey of approximately a decade before, using a similar respondent group, to determine whether the knowledge base of school students has improved in the intervening years, and whether some of their misconceptions have been eliminated. The coversheet of the questionnaire asked students to record their gender and United Kingdom year-group (grade).

Procedure

Design and administration of the questionnaire

The aim of the present study was to determine the prevalence of the ideas of school students (the "current cohort") about the greenhouse effect and to compare them with those of school students some 9 years before (the "previous cohort," Boyes & Stanisstreet, 1993). For this reason, the closed questionnaire employed was substantially similar to that used in the previous study. The original closed questionnaire had itself been developed using the responses to an open-form questionnaire completed by 60 students

in National Curriculum Year 9 (aged 13/14 years). The open questionnaire asked students to give their ideas about the nature, causes, effects, and "cures" of the greenhouse effect; some of the ideas raised, together with "scientific" ideas, were incorporated into the closed questionnaire. The questions were in 3 sections of 12 questions each. The first section was about what might happen if the greenhouse effect increased; the second section dealt with how the greenhouse effect might be made worse; the third section concerned what might be done to reduce the greenhouse effect. The questions took the form of statements to which students could respond "I am sure this is right," "I think this is right," "I don't know about this," "I think this is wrong,"or "I am sure this is wrong." Within each section, in random order, there were 6 statements with scientifically more acceptable ideas, and 6 statements with idiosyncratic ideas which had been raised in the responses to the open questionnaire. The statements, in the order in which they appeared on the questionnaire, are shown in Figure 1.

In addition, for the present study a short new section was added to probe students' concerns about, perceived knowledge of, and reported sources of information (television, school, magazines, and radio), about the greenhouse effect. The responses provided for the first of these questions (Figure 1), about concerns about the greenhouse effect, were "I am very worried," "I am a bit worried," and "I am not worried at all." The responses available to the question about how much students thought they knew about the greenhouse effect were "I know a lot," "know something," "I know a little bit," and "I hardly know anything." Similarly, the items about sources of information had the following responses provided: "I have learnt a lot," "I have learnt something," "I have learnt a bit," and "I have learnt nothing."

The questionnaire was administered to 1485 students in 30 teaching groups in British National Curriculum Years 7 (age 11/12 years), 8 (12/13 years), 9 (13/14 years), 10 (14/15 years), and 11 (15/16 years). The 6 schools were mixed sex, non-religious, Community Comprehensive schools in the north west of England. Students were assured of anonymity and were asked to complete the questionnaire individually. Examination conditions prevailed, although there was no time limit.

#	Statement
1	If the Greenhouse Effect gets bigger the earth will get hotter.
2	If the Greenhouse Effect gets bigger more people will get food poisoning.
3	If the Greenhouse Effect gets bigger there will be more flooding.
4	If the Greenhouse Effect gets bigger more fish will be poisoned in rivers.
5	If the Greenhouse Effect gets bigger more people will get skin cancer.
6	If the Greenhouse Effect gets bigger some of our tap (drinking) water will become unsafe to drink.
7	If the Greenhouse Effect gets bigger there will be more "bugs" and "pests" on crops.
8	If the Greenhouse Effect gets bigger there will be changes in the world's weather.
9	If the Greenhouse Effect gets bigger more people will die of heart attacks.
10	If the Greenhouse Effect gets bigger there will be more deserts in the world.
11	If the Greenhouse Effect gets bigger some of the ice at the North and South Poles will melt.
12	If the Greenhouse Effect gets bigger there will be more earthquakes.
13	The Greenhouse Effect is made worse by rubbish dumped in rivers and streams.
14	The Greenhouse Effect is made worse because too many of the sun's rays get to the earth.
15	The Greenhouse Effect is made worse by too much carbon dioxide in the air.
16	The Greenhouse Effect is made worse by too much ozone near the ground.
17	The Greenhouse Effect is made worse by too much litter in the streets.
18	The Greenhouse Effect is made worse by gas from rotting waste.
19	The Greenhouse Effect is made worse by radioactive waste from nuclear power stations.
20	The Greenhouse Effect is made worse by acid in the rain.
21	The Greenhouse Effect is made worse by CFC gas from spray cans.
22	The Greenhouse Effect is made worse by gas which comes from artificial fertilisers.
23	The Greenhouse Effect is made worse by holes in the ozone layer.
24	The Greenhouse Effect is made worse because the sun's rays cannot escape from the earth.
25	The Greenhouse Effect can be made smaller by having nuclear power stations instead of coal power stations.
26	The Greenhouse Effect can be made smaller by eating healthy foods.
27	The Greenhouse Effect can be made smaller by keeping beaches clean.
28	The Greenhouse Effect can be made smaller by using unleaded petrol (gasoline).
29	The Greenhouse Effect can be made smaller by reducing the number of nuclear bombs in the world.
30	The Greenhouse Effect can be made smaller by planting more trees in the world.
31	The Greenhouse Effect can be made smaller by making our electricity from wind, waves and tides.
32	The Greenhouse Effect can be made smaller by using recycled paper more.
33	The Greenhouse Effect can be made smaller by protecting rare plants and animals.
34	The Greenhouse Effect can be made smaller by not wasting electricity.
35	The Greenhouse Effect can be made smaller by reducing starvation in the world.
36	The Greenhouse Effect can be made smaller by not using cars so much.
37	What do you feel about the Greenhouse Effect?
38	How much do you think you know about the Greenhouse Effect?
	How much of what you know about the Greenhouse Effect have you learned from …
39	… television?
40	… school?
41	… newspapers and magazines?
42	… the radio?

Figure 1. The full wording of each of the 42 items in the questionnaire.

Analysis of data

The encoded responses were entered into a computer data file, and manipulated and analysed using the Statistical Package for the Social Sciences. For discussion purposes here, dichotomous data were produced by combining "sure right" with "think right" responses to produce the percentage of students who affirmed each idea and, separately, those who rejected the idea or who did not know (the remaining three categories of response). For the present cohort, in order to determine whether the proportions of students affirming a particular idea changed significantly with year-group (grade) the dichotomous data were tested for linear by linear association (Chi-square for trends). The data from the present study were also compared with those from the previous survey, again using dichotomous data, in two ways. First, overall differences across the year-groups between the proportions of students in the two cohorts affirming each idea were tested using the Mantel Haenszel test. Second, the proportions of students in the youngest year-group (Year 7, grade 6) in the two cohorts affirming each statement were compared by Chi-square analysis. The latter was repeated for students in the oldest year-group (Year 11, grade 10).

In addition, for further analysis, a variety of "scores" were produced using the original, five-response-category data. In the case of the more scientifically acceptable statements, "sure right" responses were scored as 1, "think right" responses as 0.5, "don't know" responses as 0, "think wrong" responses as -0.5 and "sure wrong" responses as -1. For the erroneous statements, the reverse scoring was used, with "sure right" responses being score as -1, "think right" responses as -0.5, and so on. For each student, an overall "knowledge score" was determined by calculating the mean of the scores for the 18 "scientific" statements, and an overall "misconception score" was determined by computing the mean for the 18 "erroneous" statements. Knowledge and misconceptions scores were calculated, in an analogous fashion, for each of the three sections of the questionnaire. For example, by calculating the mean score for the responses to the six scientific statements in the first section of the questionnaire, a "consequences knowledge score" could be determined for each student. These knowledge and misconception scores were used to compare the overall responses of the current cohort of students with those of the previous cohort (using a *t*-test). Third, links between the extent of students' concerns and, independently, their perceived knowledge about global warming, with their knowledge and misconception scores were explored by calculating Spearman correlation coefficients. Finally, analysis of variance was used to determine whether there were any links between the major reported

sources of information (television and school) and the extent of the knowledge or misconceptions of the oldest group of students.

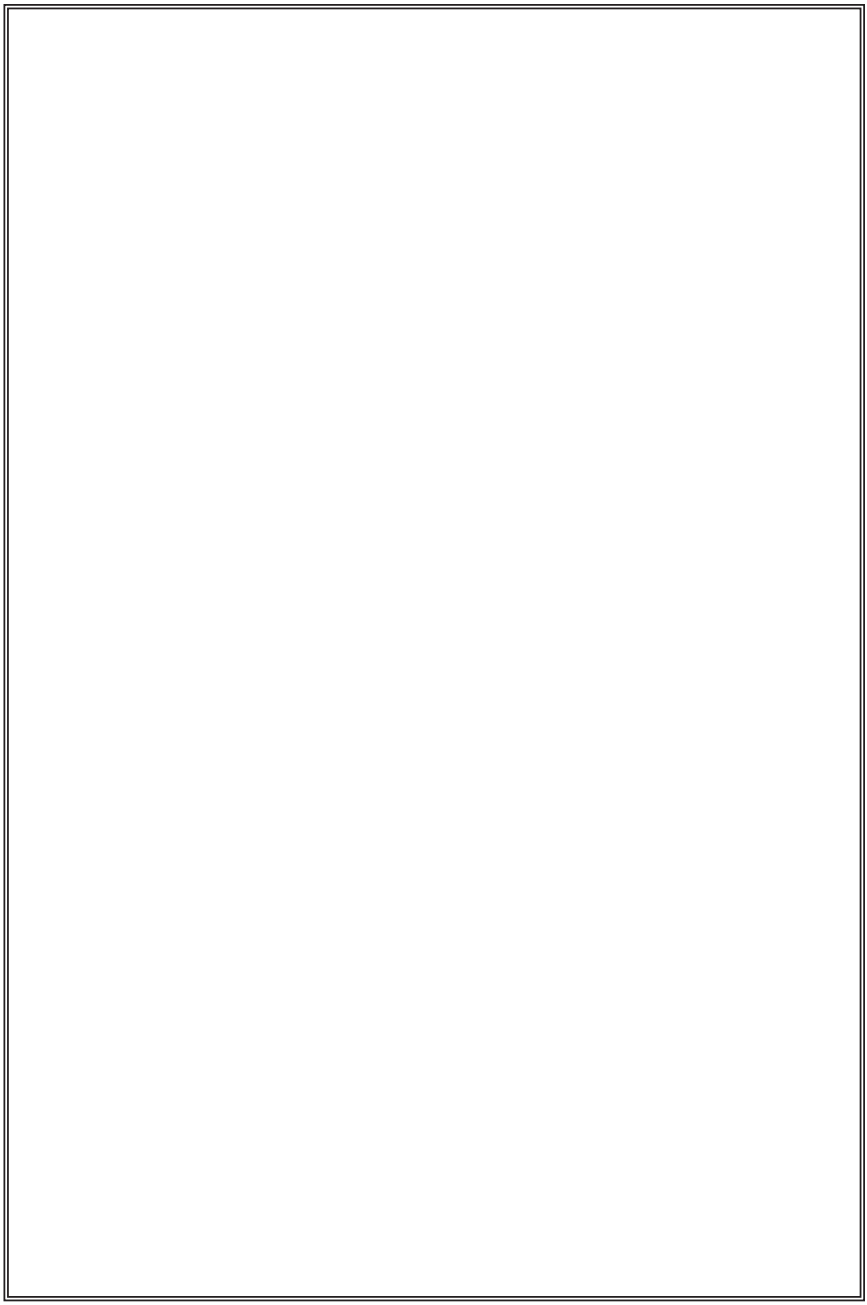
Results

Summary data for the responses to the questions about the greenhouse effect are given in Figure 2, and are shown graphically in Figure 3 ("consequences"), Figure 4 ("causes") and Figure 5 ("cures"). The responses to the questions in the final section of the questionnaire, about students' concerns, their perceived knowledge and reported sources of information about the greenhouse effect, are illustrated in Figure 6.

The graphs in Figures 3 through 5 are constructed to facilitate comparison of the distribution of responses from the present study with those of the previous study (Boyes & Stanisstreet, 1993). The upper six graphs in each of Figures 3 through 5 demonstrate the responses to "scientific" ideas, the lower six graphs refer to "alternative" ideas. On each of the graphs, the abscissa shows the five year-groups (grades); the ordinate depicts the proportions of responses. The results of the previous survey are represented by the two grey shaded areas and the white zone between them. Here, the lower grey area represents the combined "Sure right" and "Think right" responses (that is, the percentage of students who affirm the idea), the white middle area the "Don't know" responses and the upper grey area the combined "Think wrong" and "Sure wrong" responses (the percentage of students who reject the idea). In an analogous manner, the results of the present survey are shown by the two solid lines; these are the equivalent of the boundaries of the shaded areas for the previous cohort. The lower line, therefore, shows the combined "Sure right" and "Think right" responses, the area between the two lines the "Don't know" responses, and the area above the upper line the combined "Think wrong" and "Sure wrong" responses.

Ideas of school students in the present cohort

In the descriptions below, of the results of the present cohort, the percentages given are those for students who affirmed the idea (combined "sure right" and "think right" responses). Where there was a statistically significant trend, up or down, between the distribution of responses of students in the different year-groups (Chi-square test for trends, $p<0.05$) with age, the percentages reported are for students in Year 7 (grade 6), followed by those for students in Year 11 (grade 10). Where no such statistically significant trend was found, the overall percentage for students in all year-groups is given.



Data shown is for combined responses as indicated (ie affirm = sure right + think right). For each of the two cohorts, Chi2 for trends has been calculated to indicate the significance of any difference between the two extreme age groups. Across the two cohorts, overall differences in the affirming of each idea were tested using the Mantel Haenszel test. Secondly, the proportions of students in the youngest year-group (Year 7, grade 6) in the two cohorts affirming each statement were compared by Chi-square analysis. This was repeated for students in the oldest year-group (Year 11 grade 10). The statistical significance of the various tests is shown by asterisks: *** ($p<0.001$), ** ($p<0.01$), * ($p<0.05$)

Figure 2. Prevalence of school students' ideas about the Greenhouse Effect.

Students' ideas about the consequences of an increase in the greenhouse effect (Figure 3)

Most of the students, and an increasing number of the older students, appreciated that one consequence of an exacerbation of the greenhouse effect will be that the world will get hotter (63%, 87%). Similarly, most students and almost all of the older students realised that an increase in the greenhouse effect will cause changes in the world's weather patterns (62%, 90%) and some melting of the polar ice caps (60%, 84%). Rather fewer students, although more of the students in the older groups, realised that increased flooding would result from an increase in global warming (31%, 58%). In contrast, in view of the seemingly obvious link between increased global temperature and extension of deserts, it is surprising that only about a third of the students across the age groups saw the latter to be a consequence of an increase in the greenhouse effect (33%). Similarly, less than half of the group overall, and a decreasing number of the older students, appreciated that global warming could result in an increase in the range and number of crop pests (48%, 36%).

The first section of the questionnaire also contained some alternative ideas about the consequences of an increase in global warming. There were decreases through the year-groups in the proportions of students who thought that an increase in global warming would result in unsafe drinking water (42%, 22%), food poisoning (23%, 7%) or heart attacks (19%, 7%) in humans, or river pollution which harmed fish (29%, 19%). Similarly, fewer of the older students imagined that an increase in the greenhouse effect would result in more earthquakes (30%, 14%). Thus, although these ideas had been raised by some students in the original open-form questionnaire, rather few students affirmed them and the proportion of students that did decreased over this period of schooling. In contrast, more students, and an increasing proportion of the older students, thought that an increase in global warming would result in more skin cancer (41%, 75%). Thus this misconception, far from being reduced in the older students, actually increased.

Students' ideas about factors which exacerbate the greenhouse effect (Figure 4)

The second section of the questionnaire contained items which concerned possible causes of global warming. There was an increase in the idea about the basic mechanism of global warming, as described in deliberately simplistic terms (the "sun's rays cannot escape," 40%, 65%). Similarly, more of the older students knew that carbon dioxide (42%, 68%), CFCs (49%, 76%) and gas from artificial fertilisers (in fact, oxides of nitrogen, 32%, 41%) were

greenhouse gases, although the knowledge that gas from decomposition of waste (in fact, methane) contributed did not improve with age (52%). The understanding that ozone low in the atmosphere could act as a greenhouse gas actually diminished in the older students (34%, 20%).

The responses to the questionnaire items expressing alternative ideas about the causes of global warming showed that there was a diminishing mental association between global warming and physical pollutants such as rubbish in rivers (44%, 29%) or litter in the street (32%, 17%). In contrast, radioactive waste was seen by an increasing proportion of the older students as contributing to global warming (52%, 63%). About a third of the students showed some confusion between global warming and Acid Rain (37%) and more, and an increasing numbe, apparently fused ideas about global warming and ozone layer degradation (58%, 74%). Similarly, and perhaps linked to this last idea, there was an increase in the idea, for the older students, of an idiosyncratic mechanism of global warming that it is caused by increased penetration of solar radiation (46%, 56%).

Students' ideas about factors which ameliorate the greenhouse effect (Figure 5)

The third section of the questionnaire was concerned with actions which might reduce the extent of global warming. An increasing proportion of older students (43%, 63%) realised that use of forms of energy generation such as wind and wave power could make a contribution, although rather fewer (35%) thought that nuclear power was beneficial in this context, and this did not increase with age. About two thirds (62%, 67%) thought that planting trees could help reduce global warming although fewer, about half (48%), thought this true of recycling paper. A higher and increasing proportion of the students (66%, 80%) realised that vehicle emissions contributed to global warming, although only about a third (35%) thought that "saving" electricity could help.

Responses to the questionnaire items about alternative ideas in this section showed that there was a diminishing confusion between the reduction of global warming and more general environmentally or socially sympathetic behaviours such as keeping beaches clean (43%, 23%), protecting rare species (44%, 22%), reducing world starvation (22%, 7%) or eating healthy foods (31%, 11%). However, there was no such reduction in the proportion of students who connected global warming with the world nuclear arsenal (44%). Furthermore, there was an increase in the erroneous view that using unleaded gasoline would reduce global warming (47%, 67%).

Students' feelings, perceived knowledge, and reported sources of information (Figure 6)

Figure 6 illustrates the responses to the questions in the final section of the questionnaire, about students' concerns, their perceived knowledge and their reported sources of information about the greenhouse effect. For statistical analysis and in the descriptions below, the "nothing" and "a little" responses have been combined and are given as the first percentage figure, as have the "some" and "a lot" responses, which are given as the second figure. There appeared to be no alteration in the level of personal concern about global warming with year-group (grade); about a quarter of the students were "not worried," about half were "a bit worried" and the remainder were "very worried" (26%, 56%, 17%, respectively). In contrast there was an increase in the perceived level of knowledge in the older students, with more of the older students claiming to know "a lot" or at least "something" about global warming (30%, 48%). The knowledge reported to be gained from the most popular sources of information, television or school, also rose with age (28%, 46%; 46%, 63%, respectively). Fewer students reported gaining much information from magazines (21%) or the radio (10%), and this did not vary with age.

It was also possible to analyse these data further, to determine whether there were links between students' concerns, self-perceived knowledge and the reported sources of information, and the actual knowledge and misconception scores gained by the students. Links between students' concerns and their self-perceived knowledge, as well as those between their concerns and their actual knowledge scores, were tested, independently, by determining correlation coefficients using the responses of all the students in the recent cohort. The results of this are shown in Figure 7. There were statistically significant positive correlations between the extent of students' concerns and their knowledge scores (either in all areas together or for each section of the questionnaire), suggesting that those students who knew more were more concerned. However, there were also statistically significant (though much smaller) positive correlations between students' concerns and their misconception score in all these areas, suggesting that those students who affirmed more of the incorrect statements have greater worries about it. Presumably, therefore, these associations do not depend on a distinction between scientific and alternative ideas; it is as though their worry stems from their awareness.

The third column of Figure 7 shows the correlation coefficients between the various knowledge or misconception scores and the extent of the students' perceived self-knowledge. Here, statistically significant correlations

were found between knowledge scores and self-perceived knowledge but not (except in one case) between misconceptions scores and self-perceived knowledge. This would perhaps suggest the obvious: that whilst students may make a sensible estimate of the state of their own knowledge, they are not aware of the extent of their own misconceptions. Misconceptions represent a covert problem.

As discussed above, students only really claimed to have learned significant amounts about global warming from school and from television. The extent to which this related to their knowledge about, or misconceptions concerning, global warming was tested using analysis of variance (ANOVA) on the data from the oldest group of students (those who could have learned a reasonable amount from school). The results of these analyses are shown in Figure 8. This shows the significances of the coefficients from the various ANOVA tests indicating the extent to which the students' perception of having learned something from television or school relates, independently, to their knowledge or misconceptions in that area.

It can be seen that in all types of knowledge, there is a significant association between the reporting of television as a source of knowledge and the actual knowledge score—independent of their reporting about school. This implies that television might be an effective source of knowledge. On the other hand, there were no such associations between television and misconception scores, indicating that television as a medium might be significantly less powerful at challenging misconceptions. Interestingly, and in a complementary manner, there were no statistically significant links between school as a reported source of information and students' knowledge scores, but there were between this source and misconception scores. This would imply, perhaps, that schooling is better than television at challenging student's misconceptions.

Comparison of students' ideas now and a decade ago

The results of the present study were compared with those from the same questionnaire 9 years before in a number of ways. First, the overall knowledge and misconception scores of the two cohorts were compared (t-test). Then, the overall proportion of students affirming each individual idea across the year-groups was compared (Mantel Haenszel test). Finally, the proportions of students in specific year-groups were compared (Chi-square analysis). For the last comparison, the percentages given below are those for students in Year 11 of the previous cohort, followed by those for Year 11 of the present cohort. Only statistically significant ($p<0.05$) results are discussed here.

When the overall mean knowledge and misconception scores of the two cohorts of students were compared by t-test, the results showed that the present cohort gained an inferior score ($p<0.001$) for knowledge, and a superior score ($p<0.001$) for misconceptions (i.e., less misconceptions). This seems to indicate that, overall, the present cohort knows less about the greenhouse effect than did students of the previous cohort, but that fewer of the present cohort held misconceptions. Further exploration of the data enabled the responses to individual questionnaire items to be compared.

Comparison of students' ideas about the consequences of an increase in the greenhouse effect (Figure 3)

Overall, fewer of the students in the present cohort affirmed the orthodox ideas about the consequences of an increase in the greenhouse effect, that the Earth would get hotter, that there would be more flooding, that there would be changes in the weather, that ice at the Poles would melt, that more deserts would form and that crop pests would increase. Comparisons of the responses of Year 11 students in the two cohorts showed that fewer of the Year 11 students in the present cohort appreciated that global warming will result in more flooding (79%, 58%), formation of deserts (64%, 30%) or extension of the range of crop pests (51%, 36%).

In contrast, the overall responses of students across the year-groups to the items expressing alternative ideas about the greenhouse effect did not differ in a statistically significant way between the two cohorts, other than for the items concerning fish in rivers being poisoned and about skin cancer. Even here, however, there was no significant difference between the responses of the Year 11 students.

Comparison of students' ideas about factors which exacerbate the greenhouse effect (Figure 4)

Overall, fewer of the students in the present cohort were aware of the roles of carbon dioxide, CFCs, gases from artificial fertilisers (oxides of nitrogen) and from rotting waste (methane) in increasing the greenhouse effect. Within the Year 11 (grade 10) students, fewer of the present cohort knew that carbon dioxide was a greenhouse gas (80%, 68%), although more of the present cohort were cognisant of the role of ground-level ozone in this context (11%, 20%).

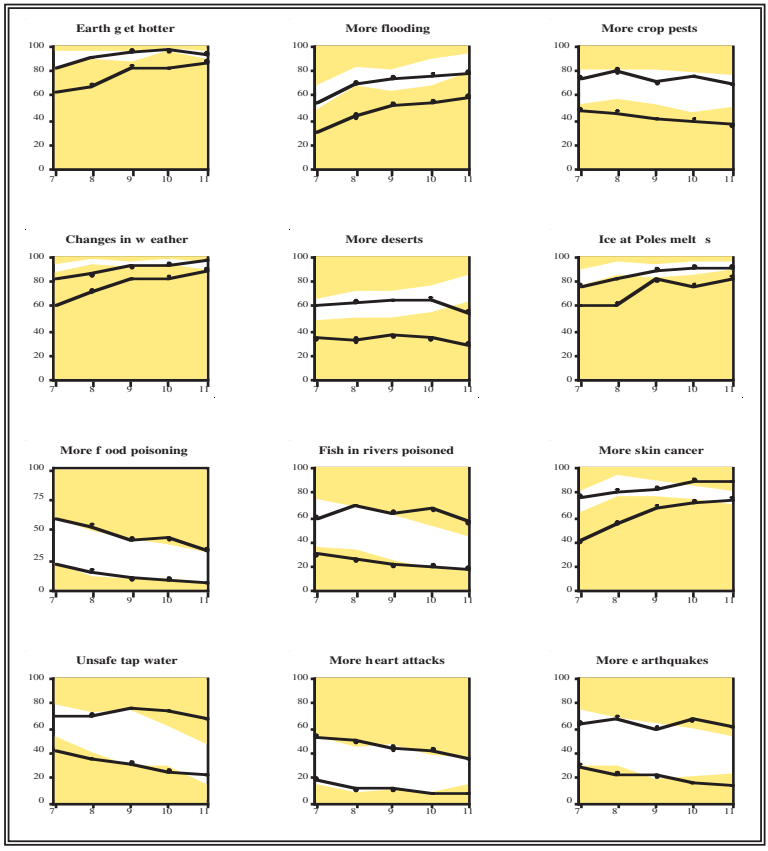
In terms of misconceptions about the causes of the greenhouse effect, rather fewer students across the year-groups in the present cohort thought that rubbish in rivers, acid in the rain, or holes in the ozone layer added to

the greenhouse effect. However, for students who had reached Year 11 (grade 10) none of these differences were significant. An interesting, if disturbing, situation was found in the case of the idea that the greenhouse effect was exacerbated by radioactive waste. Whereas fewer of the youngest students in the present cohort held this idea (80%, 52%), more of the older students in the present affirm this notion (38%, 63%). Thus, this misconception, which decreased across the year-groups in the previous cohort, now appears to be increasing in the older students.

Comparison of students' ideas about factors which ameliorate the greenhouse effect (Figure 5)

In the section of the questionnaire about possible actions to reduce the greenhouse effect, overall fewer of the students in the current cohort appreciated that planting more trees and recycling paper, use of renewable energy sources and conservation of electricity, and reduction in vehicle use could all contribute. When the responses of the oldest students, those in Year 11, were compared between the two cohorts it was found that fewer of the students in the present cohort knew about the benefits, in the context of the greenhouse effect, of nuclear power (54%, 38%), tree planting (88%, 67%), wind and wave power (78%, 63%), paper recycling (75%, 50%) or conservation of electricity (59%, 34%). The same was true of the responses to the questionnaire item about nuclear power, with fewer students in the current cohort appreciating its benefits, at least in terms of the greenhouse effect (54%, 38%).

When the responses of the two cohorts to the questionnaire items with non-scientific ideas for reducing the greenhouse effect were compared, it was found that overall fewer of the present cohort thought that keeping beaches clean, protecting rare species or replacing leaded with unleaded gasoline could contribute, whereas more of the current cohort imagined that there was some connection with use of healthy foods. However, when the responses of the oldest groups of students in the two cohorts were compared, there were no statistically significant differences. Reduction of the global nuclear arsenal was thought to help reduce global warming by fewer of the present cohort in the youngest age group (64%, 47%), but in the oldest age group this situation was reversed (22%, 40%).



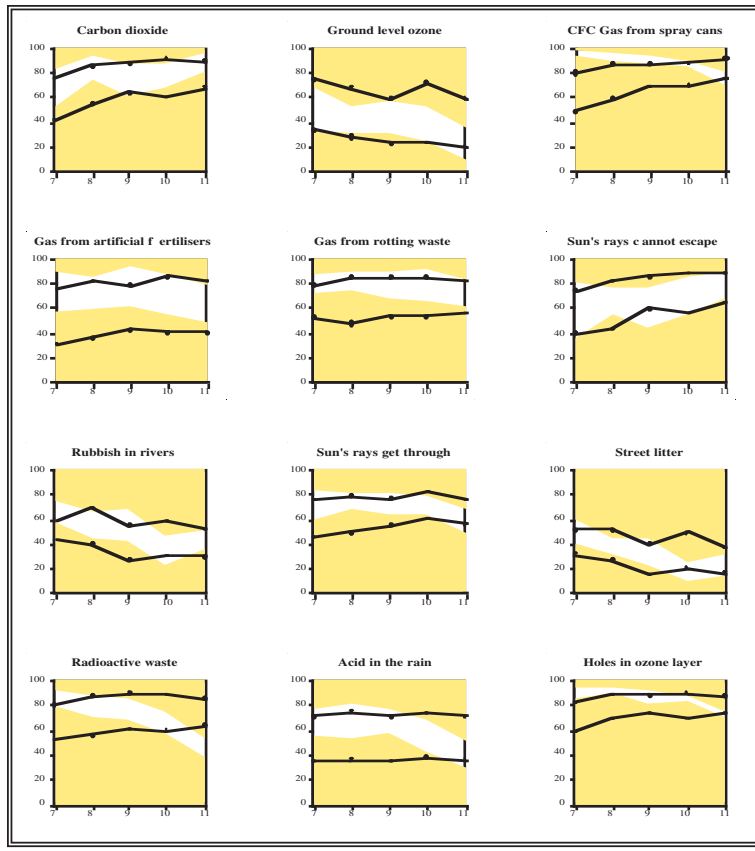
The upper six graphs in the Figure represent the distributions of responses to the scientifically-acceptable statements; the lower six graphs the distribution of responses to the statements expressing alternative, non-scientific ideas.

Within each graph, the abscissa shows the UK National Curriculum Year groups 7-11 (grades 6 -10), and the ordinate shows the percentages of different responses to the statement.

The results of the previous survey are represented by the two grey shaded areas and the white zone between them. Here, the lower grey area represents the combined "Sure right" and "Think right" responses (that is, the percentage of students who affirm the idea), the white middle area the "Don't know" responses and the upper grey area the combined "Think wrong"and "Sure wrong" responses (the percentage of students who reject the idea).

Against this background, the results of the present survey are shown by the two solid lines. Here, the two lines are the equivalent of the boundaries of the shaded areas for the previous cohort. The lower line, therefore, shows the combined "Sure right" and "Think right" responses, the area between the two lines the "Don't know" responses, and the area above the upper line the combined "Think wrong" and "Sure wrong" responses.

Figure 3. Graphs showing percentages of student responses to statements concerning possible consequences of an increase in the greenhouse effect.



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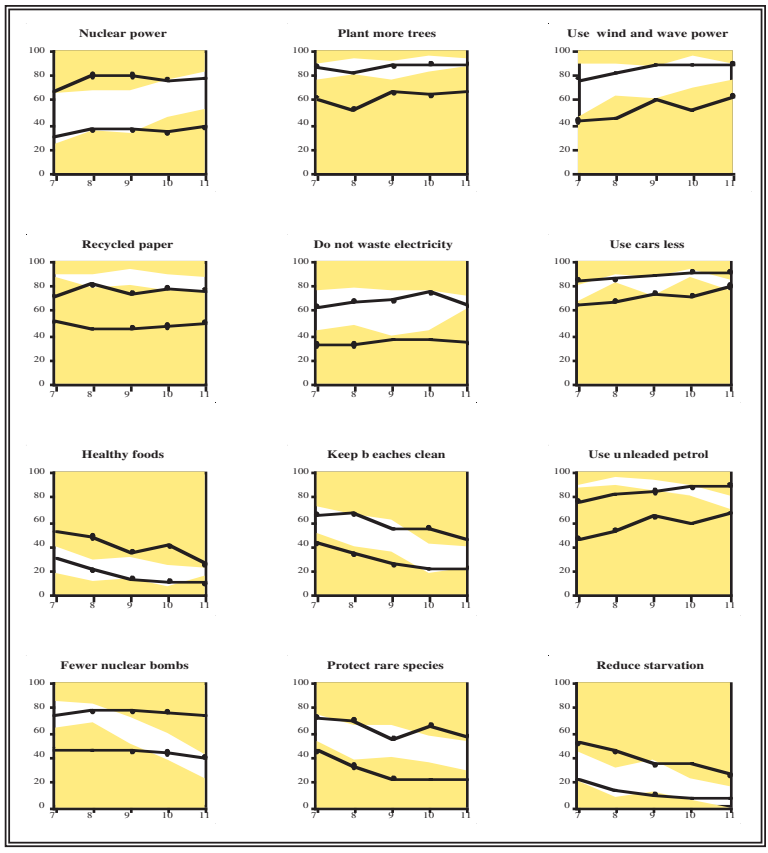
Against this background, the results of the present survey are shown by the two solid lines. Here, the two lines are the equivalent of the boundaries of the shaded areas for the previous cohort. The lower line, therefore, shows the combined "Sure right" and "Think right" responses, the area between the two lines the "Don't know" responses, and the area above the upper line the combined "Think wrong" and "Sure wrong" responses.

Figure 4. Graphs showing percentages of student responses to statements concerning possible causes of the greenhouse effect.



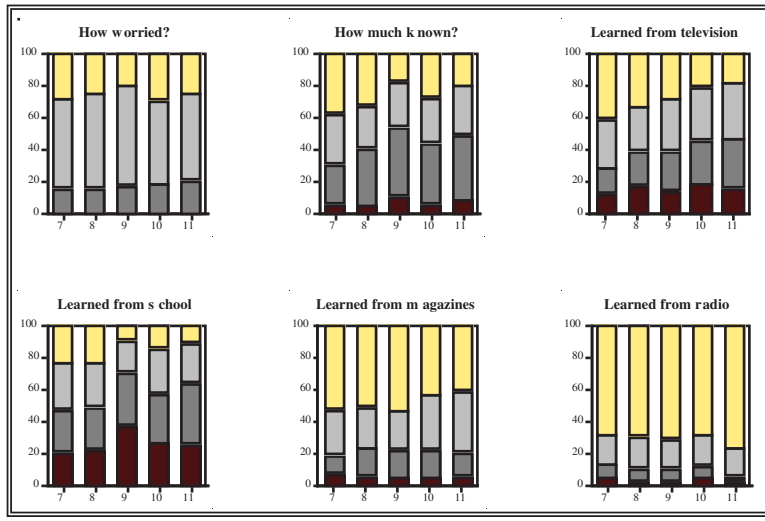
The upper six graphs in the Figure represent the distributions of responses to the scientifically-acceptable statements; the lower six graphs the distribution of responses to the statements expressing alternative, non-scientific ideas.

Within each graph, the abscissa shows the UK National Curriculum Year groups 7–11 (grades 6–10), and the ordinate shows the percentages of different responses to the statement.

The results of the previous survey are represented by the two grey shaded areas and the white zone between them. Here, the lower grey area represents the combined "Sure right" and "Think right" responses (that is, the percentage of students who affirm the idea), the white middle area the "Don't know" responses and the upper grey area the combined "Think wrong" and "Sure wrong" responses (the percentage of students who reject the idea).

Against this background, the results of the present survey are shown by the two solid lines. Here, the two lines are the equivalent of the boundaries of the shaded areas for the previous cohort. The lower line, therefore, shows the combined "Sure right" and "Think right" responses, the area between the two lines the "Don't know" responses, and the area above the upper line the combined "Think wrong" and "Sure wrong" responses.

Figure 5. Graphs showing the percentages of student responses to statements concerning possible actions to reduce the greenhouse effect.



These graphs represent data for the present cohort only. The abscissa shows the UK National Curriculum Year groups 7-11 (grades 6-10) and the ordinate shows the percentages of the different responses to the statements.

In the top left graph ("How worried?") the lowest dark section of each column represents the "very worried" responses, the next, lighter section the "a bit worried" responses and the top, lightest segment the "not worried" responses.

In the remainder of the graphs, about what students think they know, or about the role of the media, the lowest, darkest segment represents "a lot" known (or learned from a particular source), the next, lighter segment represents "something" known/learnt, the next segment "a little" known/learnt and the uppermost segment "nothing" known/learnt.

Figure 6. Graphs showing the percentages of student responses to statements concerning feelings, perceived knowledge and reported sources of information about the greenhouse effect.

Discussion

The results of this study allow us to explore the prevalence of scientific and alternative ideas about global warming held by present-day students, and the alterations in such ideas over the period of secondary schooling. In addition, affective parameters such as the degree of students' concern and the extent of their perceived knowledge were examined. Furthermore, a longer-term cross-sectional comparison can be made between the ideas of current students and those of students 9 years earlier (Boyes & Stanisstreet, 1993).

The results show that in the current generation of school students, some scientific ideas are already well known by the youngest group, whereas other ideas become established over the period of secondary schooling. The idea that the greenhouse effect will cause the Earth to get

Knowledge or Misconception Score	Correlation with the extent of students' concern (p)	Correlation with the extent of students' perceived self-knowledge (p)
All areas (consequences, causes and cures)		
Knowledge	0.30 (***)	0.43 (***)
Misconception	0.14 (***)	
Consequences		
Knowledge	0.24 (***)	0.42 (***)
Misconception	0.11 (***)	
Causes		
Knowledge	0.24 (***)	0.31 (***)
Misconception	0.14 (***)	
Cures		
Knowledge	0.25 (***)	0.30 (***)
Misconception	0.07 (*)	0.10 (***)

The table shows the associations (Spearman correlation coefficients) between students' knowledge and misconception scores and the extent of students' concern (second column) and, independently, extent of students' self-perceived knowledge (third column). The statistical significance of the associations is shown by asterisks: *** (p<0.001), ** (p<0.01), * (p<0.05)

Figure 7. Associations between students' concerns and perceived knowledge with their actual knowledge or misconceptions about the greenhouse effect.

Knowledge or Misconception Score	Extent to which television or school is seen as the source of information – statistical significance in ANOVA	
	TV	SCHOOL
All areas (consequences, causes and cures)		
Knowledge	**	
Misconception		***
Consequences		
Knowledge	**	
Misconception		
Causes		
Knowledge	**	
Misconception		***
Cures		
Knowledge	**	
Misconception		

Results from 8 different ANOVA tests, each including three variables: a knowledge or misconception score and a TV and school "score"—the latter two being the extent to which they think that TV or school has been a source of information about the greenhouse effect. The statistical significance of the contributions is shown by asterisks: *** (p<0.001), ** (p<0.01), * (p<0.05)

Figure 8. Associations between students' perception of two of their sources of information with their actual knowledge or misconceptions about the greenhouse effect.

hotter, and will result in changes in weather patterns are examples of ideas than are established early. The fact that these ideas are well-known may be driven partly by terminology. For example, "global warming" is almost synonymous with the "greenhouse effect" in lay parlance, and the term "climate change" which is commonly associated with global warming may imply changes in the weather, if students do not distinguish between "weather" and "climate." Other scientific ideas, although at a low prevalence in younger students, are acquired over the period of secondary schooling; the appreciation that carbon dioxide is a Greenhouse gas is an example. In a complementary manner, certain misconceptions, although raised by some students in the open-form questionnaire used to design the closed-form instrument, are at a low level in even the youngest group of students. The supposed links between the greenhouse effect and health, in the form of food poisoning and heart attacks, are examples. Other misconceptions, such as the purported link between global warming and rubbish in rivers or litter in the street, decline in prevalence over the period of secondary schooling. This reduction might represent the development of a degree of differentiation in thinking, in that physical, concrete pollutants are distinguished from gaseous, almost abstract pollutants. In educational terms, these categories of ideas and misconceptions present no major problem, since the majority of students acquire scientific thinking by the end of the period of schooling.

By way of contrast, some scientific ideas remain at the same level over this period. The increase in the range of deserts which will accompany global warming and, perhaps of more practical importance to students, the idea that "saving" electricity will contribute to the reduction of global warming, show this profile across the age groups. Other ideas, such as the link between global warming and expansion of the range of crop pests, and the notion that ground-level ozone contributes to the greenhouse effect, actually decrease over the period of the schooling. The latter idea illustrates a general point, that some environmental issues, like some more general scientific issues (Wolpert, 1993), are counter-intuitive. Thus, it might be difficult for students to envisage ground-level ozone as a pollutant when they are so aware of the need for the integrity of the stratospheric ozone layer to be maintained. In an analogous manner, some misconceptions, such as the supposed links between acid rain and, separately, the extent of the nuclear arsenal, with global warming were not corrected over the age groups studied. Furthermore, the imagined link between skin cancer and global warming, and the notion that substitution of unleaded gasoline would help alleviate the greenhouse effect, both increased in older students.

Comparisons of the responses of the previous and present cohorts of students showed a general similarity in the profile of ideas across the age groups, although the present cohort of students tended to know less about the scientific ideas about the consequences, causes and "cures" for global warming and held fewer misconceptions. Put another way, their "knowledge" (be it right or wrong) about, or familiarity with, the issues surrounding the greenhouse effect was less than that of students 9 years before. This may reflect, in part at least, the fact that global warming as an environmental issue has, to some extent, slipped from the public and political agenda, to be replaced by other environmental issues. Ozone layer depletion became a public concern, perhaps because of its more immediate threat to public health in terms of melanoma, perhaps because of well-publicised steps which individuals could take to reduce this risk, by avoiding excessive exposure to solar radiation and by using UV-barrier creams. More recently, this issue has in turn been replaced by media coverage and public concern about possible health and environmental problems resulting from the use of genetically modified organisms (Hill, Stanisstreet, & Boyes, 1999). In all of this, the present generation of school students may not have been exposed to the same extent to information and argument about global warming as had those in the previous study.

Although there was no equivalent on the questionnaire used 9 years previously, a short section added to the questionnaire used in the present study gave some indication of students' concerns, perceived knowledge and reported sources of information about the greenhouse effect. There was little change in the level of concern about global warming expressed by students in the different age groups; perhaps sensitivity or otherwise to environmental problems is an innate characteristic, not influenced by the extent of knowledge. Likewise, there was little change in students' perceptions of the extent of their own knowledge about global warming. In this case, it may be that the increasing knowledge base of students is compensated for by a rise in the level of their own expectations. Of the popular media offered by the questionnaire, students across the age groups reported that they had learned more about the greenhouse effect from television than from radio or magazines. This probably reflects the dominance of television in young people's lives, in that television is a "strong" medium and that students spend more time watching television than addressing other the media, as much as any differences in the environmental content of the various media. Indeed, there appeared to be a correlation between the degree to which students reported gaining information from television, and the extent of their knowledge of scientific ideas about global warming. There

was, however, no such correlation between the extent of students' misconceptions and their reported use of television as an information source. In contrast, schooling appeared to play more of a role in challenging students' misconceptions.

We see important implications here for teaching and learning about environmental, and perhaps wider, issues. In the classroom context, students can have their ideas challenged by their peers and by their contemporaries. Television, although a "strong" medium with a well-informed and attractive content, offers no such feedback. Any information gained from such a uni-directional source may be misinterpreted to fit with pre-existing conceptual frameworks. Alternatively, conceptual frameworks may be distorted, but not necessarily corrected, to accommodate it. In contrast, teachers can interact with their students in an iterative manner, informally eliciting students' own ideas, challenging misconceptions and helping students to establish mental frameworks which are congruent with scientific understanding. This has consequences for the increased use of computer-based learning, particularly that which involves drawing information from Internet sources, since this is also a uni-directional process. We therefore offer the following heresy, that the current, apparently unbridled, enthusiasm for computer-based learning should be tempered by an appreciation of its potential pedagogical/educational limitations.

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Notes

[1] The greenhouse effect occurs because of the presence of certain gases in the atmosphere. Most of the solar energy which reaches the Earth passes through the atmosphere with only a little obstruction at some frequencies. As the Earth warms due to this incident radiation, it begins to emit radiation. However, the atmosphere prevents a greater proportion of this lower-energy radiation from passing through, and so the Earth heats up further until equilibrium is reached. Some degree of greenhouse effect is "natural," indeed vital to life on Earth—it is estimated that the Earth is about 33°C warmer than it would be without any greenhouse effect. global warming

is thought to be caused by an exacerbation of the greenhouse effect due to anthropogenic atmospheric pollutants. Some of the greenhouse gases which contribute to global warming are carbon dioxide, chlorofluorocarbons (CFCs), methane, nitrous oxide. Ground-level ozone and water vapour in the atmosphere may also contribute to global warming.

In this paper, we use the terms "global warming" and "greenhouse effect" somewhat loosely and interchangeably, to avoid over-contorted sentence construction.

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