International Journal of Environmental & Science Education
Vol. 6, No. 1, January 2011, 79-98

What Greek secondary school students believe about climate change?

Georgia Liarakou, Ilias Athanasiadis, Costas Gavrilakis

Received 16 May 2010; Accepted 15 September 2010

The purpose of this study was to investigate what Greek secondary school students (grades 8 and 11) believe about the greenhouse effect and climate change. A total of 626 students completed a closed-form questionnaire consisting of statements regarding the causes, impacts and solutions for this global environmental issue. The possible influence of three factors – i.e. educational level, gender and previous participation in Environmental Education extracurricular programs – on students' ideas was examined. The results suggest that eleventh graders were much better informed than eighth graders although some of the misconceptions reported in the literature (such as the cause-effect relationship between the greenhouse effect and ozone layer depletion) persist, irrespective of educational level. Students have fairly clear ideas of impacts while they seem to be somewhat confused about solutions and especially causes. Among the possible explanations of these trends, the logical sequence of physical consequences and students' difficulty in recognizing causes that presume specific scientific knowledge are emphasized. In addition, the role of information sources, especially television which emerged as the dominant source, is discussed. Finally participation in Environmental Education programs appears to be a critical factor since it has clearly influenced students' ideas in a positive way.

Keywords: climate change, greenhouse effect, environmental education, Greece, secondary school students' ideas

Introduction

Today, more than ever before, climate change appears to be a fact or at least an observable process in, for instance, the increase of the average global air and ocean temperature, the widespread melting of ice and rise of the average sea level worldwide (Intergovernmental Panel on Climate Change [IPCC], 2007a). Even though it is very difficult for scientists to distinguish the extent to which natural processes and human activities each contribute to the greenhouse effect, there is strong evidence today that most of the observed global warming over the past fifty years is attributable to human activities (United Nations Environment Programme / United Nations Framework Convention on Climate Change [UNEP/UNFCCC], 2002).

Since people, individually or collectively, are responsible for the aggravation of this phenomenon, a review of the dominant development model and of our lifestyle is needed. Whereas such a radical change requires a systematic and lasting effort, education seems to be the safest way to achieve it. Climate change is a topic that has been already included in the curricula of several countries (e.g. United Kingdom, Australia). Environmental Education (EE) suggests a

ISSN 1306-3065

http://www.ijese.com/

learning process through which, contrary to the traditional fragmented curricula, the issue of climate change can be approached in an integrated way, i.e. in an interdisciplinary, systemic and holistic way (Liarakou & Flogaitis, 2007). Such an approach is needed so that the multiple dimensions (i.e. social, economic, physical etc.) of this phenomenon can be better examined and understood. Indeed, among the best known environmental issues, climate change is probably the most critical, complicated and abstract. Thus the knowledge and capabilities required to understand the issue of climate change and, even more so, to become consciously involved in acting to prevent it, are diverse, complex and therefore not easy to acquire.

Several studies have been reported in the literature about school students' perceptions, ideas and understanding of climate change and the greenhouse effect, either exclusively or in conjunction or comparison with other environmental issues. These studies attempt to interpret how students perceive this phenomenon in order first of all to improve the overall learning process. The first relevant studies were published in the late 1980s (Hansen, 2010), although the subject was not explored in detail until the following two decades. E. Boyes, M. Stanisstreet and their collaborators have studied different groups, investigating their ideas about the causes, consequences and cures of the greenhouse effect and global warming, using mainly closed-form questionnaires. Their studies are more of British and less of American students. In particular, they have explored the ideas of both elementary (Francis, Boyes, Qualter, & Stanisstreet, 1993) and secondary school students (Boyes, Chuckran, & Stanisstreet, 1993; Boyes & Stanisstreet, 1993; Boyes & Stanisstreet, 2001; Daniel, Stanisstreet, & Boyes, 2004). They have also focused on ideas about the contribution of motor vehicles on the greenhouse effect and other issues (Batterham, Stanisstreet & Boyes, 1996; Boyes & Stanisstreet, 1997a; Lesson, Stanisstreet, & Boyes, 1997). Furthermore, they have found interesting results regarding the greenhouse effect while investigating ideas about the ozone layer held by secondary school children (Boyes & Stanisstreet, 1994). From these studies a common misconception has emerged, which is that there is a cause-effect relationship between the greenhouse effect and depletion of the ozone layer. Focusing on this relationship Boyes and Stanisstreet (1997b) attempted to quantify the models dominant in the minds of 13- and 14-year- old children. The most common connection is that the "holes" in the ozone layer allow more solar energy to arrive at the earth, contributing to the exacerbation of the greenhouse effect. In addition, Boyes and Stanisstreet (1998) investigated perceptions of secondary school students (also 13-14 years old) about how global environmental issues, such as the greenhouse effect, cause skin cancer. They recently published an investigation of Chinese high school students (11-16 years) with regard to actions that help reduce global warming (Boyes, Stanisstreet & Yongling, 2008) and a study of Turkish students (15-16 years old) about the causes, consequences and cures of global warming (Kilinc, Stanisstreet, & Boyes, 2008).

In addition to the above research team, several researchers have also explored secondary school students' conceptions of climate change and the greenhouse effect. For example: Rye, Rubba and Wiesenmayer (1997) investigated a group of US students from grades 6-8; Fischer (1998) explored a group of varying ages in New Zealand; Meadows and Wiesenmayer (1999) discussed school-age children's confusion of climate change and ozone layer depletion that has been identified by research and suggested strategies to combat this confusion; Andersson and Wallin (2000) emphasized how Swedish students in grades 9 and 12 (15±16 and 18±19 years old respectively) explain the greenhouse effect and how they think the reduction of CO_2 emissions would affect society; Pruneau et al. (2001) examined similar ideas among various age groups (including teenagers, 13-14 years) in Canada aiming to propose strategies for education in climate change. Recently, Shepardson, Niyogi, Soyoung and Charusombat (2009) investigated the ideas of 7th grade students from the US Midwest regarding global warming and climate change.

In an effort to assess specific learning processes, Mason and Santi (1998) investigated how the socio-cognitive interaction that developed in group discussions in an EE curriculum unit helped to change the ideas of 5th graders (age 10-11 years) in Padova, while Pruneau, Gravel, Bourque and Langis (2003) experimented with a socio-constructivist and experiential process for climate change education with Canadian students 13-14 years old. Within this context Devine-Wright, Devine-Wright and Fleming (2004) conducted empirical research with UK children (9-12 years old) and adults, aiming to investigate the influence of a cooperative learning environment upon their beliefs and perceived ability to act on global warming.

Research on this topic in Greece is limited. Koulaidis and Christidou (1999) reported on the ideas of Greek primary school students (11-12 years old) and analysed models of thinking about this phenomenon. Investigating primary school children's models of the ozone layer, Christidou and Koulaidis (1996) reported the confusion between the greenhouse effect and ozone layer depletion that had been reported elsewhere in the literature. This confusion was likewise reported in the study by Boyes, Stanisstreet and Spiliotopoulou-Papantoniou (1999) who investigated perceptions of Greek school students (age 11-16 years) about the ozone layer. However, apart from the study by Papageorgiou and Tsiropoulou (2004) of the impact of teachers' experiments on high school students' knowledge and explanations of aspects of the greenhouse effect, no other study focusing on Greek secondary school students' ideas about climate change has been published in the international literature.

It should be noted that the studies mentioned above were conducted when the greenhouse effect was virtually absent from the Greek curriculum. Since then, a new curriculum was introduced (in 2003) and the greenhouse effect has been introduced in both primary and secondary school curricula. Although this issue is briefly presented in the science curriculum in all grades, it is covered in detail in grade 8 Chemistry and in grade 11 Chemistry and Environmental Sciences. This issue can be also examined in the context of extra-curricular EE programs. These programs consist of various learning activities that take place both in and outside of school. In primary school there is time devoted to such activities but in secondary school these programs are actually implemented out of timetable. Although teachers and students get involved in a voluntary basis, these programs are quite popular in the Greek schools. Apart from school, in recent years some organisations (mainly NGOs, i.e. WWF-Hellas) have created educational material to inform students about the greenhouse effect and climate change.

The aim of the present study was to investigate Greek secondary school students' basic ideas about the greenhouse effect in terms of some common physical aspects of the phenomenon and its main socio-political dimensions (e.g. environmental refugees). In particular, it has explored the ideas of students living in the Aegean archipelago of the Dodecanese. These islands are significantly more vulnerable to the impact of climate change (especially to rising sea levels) than the mainland. On the other hand, the region is characterized by an especially rich renewable energy potential (i.e. solar and wind energy) which could allow the local community to reduce its contribution to the greenhouse effect. However, this potential has not been yet adequately exploited. In fact these islands meet their energy needs mainly with oil. Furthermore, most Aegean islands suffer from water shortages due to the rather limited precipitation in the region, which are likely to become worse owing to the exacerbation of the greenhouse effect. These facts, among others, attest to this region's special relationship with climate change and suggest the main reasons why we chose to investigate the ideas of students from the Dodecanese.

Initially we attempted to investigate students' basic ideas about the causes, impact and potential solutions to the greenhouse effect. We also reported the students' sources of information on this issue, and examined whether three factors can be correlated with their ideas, i.e. (a) educational level, (b) gender, (c) previous participation in EE. Educational level and gender have

already been investigated in the literature. However the possible contribution of previous participation in EE to shaping students' ideas has not been studied. Findings could be useful both to improving the learning process and to creating appropriate educational material.

Methodology

Students' ideas about climate change and the greenhouse effect are largely known through many studies, as outlined in the introduction. Given this fact, a quantitative methodological orientation was selected as being more appropriate, since our main aim was not to analyse in-depth but to compare, correlate and generalise the results (Michail, Stamou, & Stamou, 2007; Summers, Kruger, Childs, & Mant, 2000).

The Instrument

Thus our survey was based on a closed-form questionnaire. The questionnaire consisted of 22 statements about causes, impacts and actions or proposals to help mitigate the greenhouse effect and climate change. Respondents could reply "I agree", "I disagree" or "I don't answer". The statements in the questionnaire were divided into three categories: eight questions were about causes, eight about impacts and six about potential solutions. There were also statements about causes that referred to potential solutions (see Table 2 - statements 3 and 5). Here there was a possibility of double checking these statements. Each category consisted of an equal number of randomly sequenced statements. Almost all statements, both true and false, were drawn from the literature as scientifically proven facts or soundly based assessments. Participants were asked to provide some demographic information about themselves, such as their gender and educational level. They were likewise asked to check off the types of resources (e.g. school, TV, magazines etc.) they used to learn about the greenhouse effect. Next, they had to state: (a) whether they had already participated in EE programs and (b) the subject of these programs.

Sampling

The participants in this study comprised students in the schools of the southern Dodecanese Islands. During sampling we endeavoured to include representative groups of school children in the region through the use of two key parameters: the school type, either *gymnasio* (junior high school, grade 8) or *lykeio* (senior high school, grade 11) and its location (urban or rural). Taking into account these criteria, a random sampling of schools was applied in such a way that in the final sample the number of participants in these sub-groups was proportional to the student population in the southern Dodecanese region. The questionnaire was administered to 638 students during a routine class to ensure a high response rate. Twelve questionnaires were given back with serious omissions and they were not processed since they could not be coded. The questionnaire was correctly completed by 626 secondary school students, studying in the second year of *gymnasio* (13-14 years old - grade 8) and the second year of *lykeio* (16-17 years - grade 11). The characteristics of our sample are presented in the Table 1.

Testing the Instrument – Analysing the Data

Since the instrument was developed by the researchers, a reliability analysis was conducted to examine the internal consistency of its items. Cronbach's alpha was 0.82, a value implying that the instrument was indeed reliable. It should also be noted that the questionnaire was pilot tested

Table 1. Basic demographic characteristics of the sample

Characteristic	Female	Male	N/R	Total
School type				
Gymnasio (grade 8)	153 (44.48%)	185 (53.78%)	6 (1.74%)	344 (100%)
Lykeio (grade 11)	146 (51.77%)	133 (47.16%)	3 (1.07%)	282 (100%)
School location				
Urban	139 (46.65%)	155 (52.01%)	4 (1.34%)	298 (100%)
Rural	160 (48.78%)	163 (49.70%)	5 (1.52%)	328 (100%)
Total	299 (47.76%)	318 (50.80%)	9 (1.44%)	626 (100%)

with 48 students, a representative sub-sample, in addition to the typical sample. Totally, 26 students were 8^{th} graders while 22 were 11^{th} graders. This group consisted of 23 girls and 25 boys. The questionnaire was anonymous. It was administered to students at the end of the last semester when the students had already been taught about the greenhouse effect. Before the students completed the questionnaire, it was made clear to them that their replies would in no way affect their grades, in order to encourage free expression and to avoid anxious participation. We chose to set no time limit.

Apart from the basic descriptive statistics, several contingency tables were developed during the data analysis so that correlations between particular variables were tested. Cluster analysis was likewise applied to examine how the students are distributed into groups with similar characteristics.

Results

In conformity with the main topics of the questionnaire, the results are presented in three parts: regarding causes, impacts and cures of the greenhouse effect. At the same time, interrelations and comparisons with some former studies referring to the same age range (12-18 years) are highlighted. A percentage is given for each statement from all students, followed by a parenthesis containing the percentage of grade 8 (first) and grade 11 (second). In this way the reader has a direct view of the main trends in the two grades, regardless of possible statistically significant differences.

Later, we focus on three parameters that were expected to influence students' ideas: their educational level, gender and previous participation in EE programs. Applying chi-square tests, we learned the degree to which these factors influenced students' ideas. Finally, we outline the characteristics of four groups as they emerged in the cluster analysis applied to the sample. Students' answers to the 22 statements in the questionnaire are reported in the Table 2.

Causes

First of all, 60.54% (50.87% - 72.34%) of students knew that carbon dioxide is a greenhouse gas since they agreed with statement 11. Moreover, 57.67% (49.13% - 68.09%) seemed to know the

Table 2. Students' ideas about the causes, impacts and solutions to the greenhouse effect

Statement	Cat*	True/ False	Agree (%)		Disagree (%)		N/A (%)	
			Gr.8	Gr.11	Gr.8	Gr.11	Gr.8	Gr.11
1. During last years the average global sea level has been rising.	I	T	57.27	70.57	34.01	20.57	8.72	8.87
2. The greenhouse effect will not bring changes in the global food production.	I	F	18.90	8.87	56.10	82.62	25.00	8.51
3. The use of solar energy exacerbates the greenhouse effect.	C	F	34.30	30.50	42.15	57.09	23.55	12.41
4. Natural gas does not contribute to aggravating the greenhouse effect.	C	F	37.50	41.13	25.00	34.75	37.50	24.11
5. Using hydrogen as energy source does not aggravate the greenhouse effect.	C	T	29.94	37.59	24.42	24.11	45.64	38.30
6. The ozone layer depletion exacerbates the greenhouse effect.	C	F	59.59	67.73	19.19	15.25	21.22	17.02
7. Wind energy will contribute to combating the greenhouse effect.	S	T	46.22	51.42	19.48	21.63	34.30	26.95
8. The use of artificial fertilizers increases the carbon dioxide in the atmosphere	C	F	44.48	50.71	25.58	28.37	29.94	20.92
9. Incandescent light bulbs save energy.	S	F	43.90	34.40	27.91	42.91	28.20	22.70
10. TV does not consume energy when it is turned off by remote control.	S	F	18.02	8.16	71.80	87.23	10.17	4.61
11. Carbon dioxide is a gas that has contributed to aggravating the greenhouse effect.	C	T	50.87	72.34	21.22	11.35	27.91	16.31
12. During the last years, the ice cover of Earth's two polar regions has increased	I	F	15.41	8.51	72.09	86.17	12.50	5.32
13. The greenhouse effect will not lead to displacement of human population.	I	F	17.15	11.35	57.56	76.60	25.29	12.06
14. Greenhouse gases exist for a million years contributing to the creation of life.	C	T	27.62	33.33	34.01	38.30	38.37	28.37
15. The Kyoto Protocol concerns the reduction of the greenhouse gasses.	S	T	20.06	36.52	20.93	10.28	59.01	53.19
16. One of the impacts of the greenhouse effect will be the appearance of new diseases.	I	T	55.52	74.47	20.06	13.83	24.42	11.70
17. With the passage of time, the average global temperature rises.	I	T	66.28	85.11	15.70	7.80	18.02	7.09
18. Renewable energy sources do not contribute to mitigating the greenhouse effect.	S	F	24.13	16.67	50.00	64.18	25.87	19.15
19. The growing incidence of skin cancer in recent years is due to the greenhouse effect.	I	F	39.83	52.84	32.27	27.66	27.91	19.50
20. Due to the greenhouse effect, extreme weather events are very likely to become more frequent and intense.	I	T	59.30	87.59	19.77	6.38	20.93	6.03
21. Carbon dioxide increases in the atmosphere because of fossil fuel combustion.	C	T	49.13	68.09	22.97	9.93	27.91	21.99
22. The use of public transport can contribute to mitigating the greenhouse effect.	S	T	45.64	54.96	27.62	31.21	26.74	13.83

* Category: C=Causes, I=Impacts, S=Solutions

main source of this gas, by agreeing with statement 21 that the combustion of fossil fuels increases carbon dioxide in the atmosphere. It is evident that in both cases there has been a visible improvement in the accuracy of students' ideas between grade 8 and grade 11.

Similar percentages for both grades were reported in the literature some years earlier with regard to CO_2. Children, even at the age of 11 (with a growing tendency as their age increases), appear to have quite a clear perception of the role of this gas (Boyes & Stanisstreet, 1993), although there are findings contesting such a trend (i.e. Fischer 1998). Recently Kilinc, Stanisstreet, and Boyes (2008) reported a very high percentage (86%) of students aged 15-16 that were aware of the role of CO_2. Boyes et al. (2008) found that an average of 61% of students are aware of the problem with oil, and regarding coal, perception of the problem grows with age from 61% (11 years) to 80% (16 years).

With respect to the causes of the greenhouse effect, among the eight related statements, four aimed to reveal whether the students knew the energy types responsible for exacerbating the phenomenon. The case of fossil fuels was mentioned above (statement 21). It is rather surprising that only 48.88% (42.15% - 57.09%) of students believed that the use of solar energy does not exacerbate the greenhouse effect (statement 3). This percentage is incommensurate with the higher knowledge level of teachers working in the region (Dodecanese) with respect to solar energy as a "green" type (Liarakou, Gavrilakis, & Flouri, 2009). Even fewer students, 33.39% (29.94% - 37.59%), knew that hydrogen does not contribute to aggravating the greenhouse effect (statement 5). This percentage, however, is not so unexpected, given that hydrogen is still a limited known energy source about which there is still considerable scientific uncertainty (Flynn, Bellaby, & Ricci, 2005). This is why 42.33% (45.69% - 38.30%) of students did not express a clear position. Regarding natural gas (statement 4) in particular, the majority of students either wrongly considered that it does not contribute to the greenhouse effect (39.14% in total, 37.50% - 41.13%) or avoided expressing an opinion (31.47% in total stated "N/A"). Although natural gas is a "cleaner" fossil fuel than oil and coal, both methane (the main component of natural gas) and the products of gas combustion (i.e. CO_2) are greenhouse gases. This fact probably led to a misconception which has already been reported in the literature (Devine-Wright, 2003). In fact, in Greece today, natural gas is widely promoted as an economical and environmentally-friendly energy source, in contrast to traditional sources such as oil and lignite. Taking into account the answers given to the statements 11, 21 and 4, it would appear that a large proportion of students did not perceive natural gas as a fossil fuel.

With regard to statement 8, 47.28% (44.48% - 50.71%) of the students erroneously answered that the use of artificial fertilizers increases the concentration of CO_2 in the atmosphere. Perhaps these students were somewhat confused, given that artificial fertilizers are not responsible for CO_2, but rather for emissions of other greenhouse gas, namely the nitrous oxide. The students seemed to be confused about the role of fertilizers in general, since in the literature (i.e. Boyes & Stanisstreet, 1993) usually about one third of them, regardless their age, cannot answer ("*don't know*") relevant questions/statements.

Regarding causes, there is also a statement deriving from what is probably the most common misconception emerging in the literature; that is the cause-effect relationship between the greenhouse effect and depletion of the ozone layer (Boyes, & Stanisstreet, 1993; Boyes, & Stanisstreet, 1994; Boyes, & Stanisstreet, 2001; Boyes et al., 2008; Christidou, & Koulaidis, 1996; Daniel et al., 2004; Kilinc et al., 2008; Pruneau et al., 2001; Rye et al., 1997). Perhaps the only study suggesting that students can overcome this fallacy is that of Shepardson et al. (2009). The findings of our study confirmed that students are subject to this cognitive confusion, since 63.26% (59.59% - 67.73%) of them agreed that the ozone layer depletion brings about an exacerbation of the greenhouse effect, while 19.33% (21.22% - 17.02%) expressed no opinion (statement 6). It should be noted that a decade earlier, Boyes et al. (1999), exploring ideas about the ozone layer depletion, reported considerably lower proportions of Greek students holding this misconception.

Due to the emphasis currently given to the negative consequences of climate change, the positive natural function of the greenhouse gases in supporting life on our planet is often underestimated or less known. Students frequently do not know the "protective" role that the greenhouse gases covering our planet have played for millions of years. That is why only 30.19% (27.62% - 33.33%) of students gave the right answer to the statement 14.

Impacts

Eight statements presented true or false aspects of the greenhouse effect and climate change impacts. These impacts were distinguished between those directly related to changes in the earth system and those related more obviously to people's lives, even though global climate change influences every form of life and every place on Earth in some way.

A strong majority of students, 74.76% on average, rightly believed that the average global temperature is increasing as the years go by (statement 17). This high proportion, however, was mainly due to 11th graders (66.28% - 85.11%), a tendency reported on the most impact statements. Shepardson et al. (2009) have reported an even larger share of American 7th grade students who believe that the weather will get warmer. Even more students, 78.43% (72.09% - 86.17%) were not fooled by the false statement 12, that the polar ice cover has been growing in recent years. A step forward, 63.26% (57.27% - 70.57%) of participants stated that the average global sea level has risen in recent years (statement 1), a proportion considerably higher than that found by Shepardson et al. (2009). Also, a high proportion of students, 72.04% (59.30 - 87.59%), agreed that extreme weather events are very likely to become more frequent and intense due to climate change (statement 20). In general, the high proportions of correct answers reported in this sub-set of statements confirm the results of other studies (Boyes & Stanisstreet, 2001; Kilinc et al., 2008). This finding probably implies satisfactory understanding of the "chain of impacts" outlined by the rising temperature, intensification of extreme weather phenomena, melting of the polar ice cap and rise of the sea level. These are precisely the four statements constituting a coherent set that represents the "Well-known consequences" according to Boyes and Stanisstreet (1992), Boyes and Stanisstreet (1993).

With respect to the impact of physical consequences that are directly related to human activity, most people, i.e. 68.05% (56.10% - 82.62%), believed that climate change will bring changes in global food production (statement 2). It is quite impressive that 11th graders were far better informed than 8th graders on this issue. It should be noted that other studies have reported remarkable percentages (even if not so high, i.e. about 50%) of students who believe that when the greenhouse effect is magnified, there will be more insects and pests on crops (Boyes & Stanisstreet, 1993; Jeffries, Stanisstreet & Boyes, 2001). Furthermore, 66.13% (57.56% - 76.60%) of participants disagreed with the statement that climate change will not lead to displacement of human population (statement 13). A similarly high percentage of participants 64.06% (55.52% - 74.47%) believed that new diseases will appear due to the greenhouse effect (statement 16). Indeed, both migration and the increase of health risks are among those impacts that are expected by the IPCC with high degree of confidence (Intergovernmental Panel on Climate Change [IPCC], 2007b). On the other hand, a remarkable 45.69% of students (39.83% - 52.84%) agreed with the statement that increased skin cancer was due to the greenhouse effect (statement 19). That was the only statement relating to impacts that was wrongly or not answered at all by the majority of students and the only one in which 8th graders gave more correct answers than 11th graders. In fact, this is another common misconception appearing in the relevant literature (Boyes, & Stanisstreet, 1993; Boyes, & Stanisstreet, 1998). Even somewhat older students appear to hold this erroneous perception (Boyes, & Stanisstreet, 1992; Jeffries et al., 2001). According to Boyes and Stanisstreet (1998) many students confuse the action of heat rays with that of UV rays;

in fact this is a misconception indicating a model held by many students due to which they perceive the greenhouse effect and ozone layer depletion as being very closely related.

Solutions

The third set consisted of three statements referring to general topics that are to some extent associated with political choices and three statements that represent citizens' choices or actions.
With regard to the general topics, less than a third of students, 27.48% in total (20.06% - 36.52%), seemed to be aware that the Kyoto Protocol deals with the reduction of the greenhouse gases, and the majority, 56.39% (59.01% - 53.19%), avoided taking a position on statement 15. This finding is very interesting since the Kyoto protocol is regarded as the most essential global political action for limiting emissions of greenhouse gases. On the other hand 56.39% (50.00% - 64.18%) of students recognised that renewables contribute to mitigating the greenhouse effect (statement 18). In relation to other studies (Boyes, & Stanisstreet, 1993; Boyes et al., 2008; Daniel et al., 2004) these percentages are significantly lower. Moreover, 48.56% (46.22% - 51.42%) of students stated (statement 7) that wind energy could contribute to the reduction of the greenhouse effect. That was an unexpectedly low percentage, given that in literature wind energy seems to be in general a widely known and familiar renewable energy type (Liarakou et al., 2009). Accordingly, a remarkable percentage (30.99% in total) did not reply.

With regard to the statements that represent citizens' choices, it was surprising that 39.62% (43.90% - 34.40%) of participants erroneously stated that incandescent bulbs save energy (statement 9). Conversely, 78.75% (71.80% - 87.23%) of the students that disagreed with statement 10, knew that when the TV is turned off just by remote control, it doesn't stop consuming energy. Finally, no more than 49.84% (45.64% - 54.96%) of the students stated that using public transport can contribute to remedying the greenhouse effect, while 20.93% in total did not reply (statement 22). In similar studies, there is much broader agreement that the greenhouse effect can be reduced by not using cars so much (Boyes, & Stanisstreet, 1993; Boyes, & Stanisstreet, 2001; Boyes et al., 2008; Daniel et al., 2004; Francis et al., 1993; Kilinc et al., 2008). Students in this study seemed in particular not to appreciate the role of public transport. In all fairness, it should be noted, however, that on many Dodecanese islands public transport may not be an issue that really concerns the students since the population density, the structure of settlements and the overall scale of the islands limit the need for public transport. On the other hand there are specific cities that encounter serious traffic problems (especially during the summer tourist period) given that citizens mainly prefer their own cars.

In Brief… Key Comparisons among the Categories

In an effort to summarise the results analysed above, several interesting conclusions have emerged (see Figures 1 and 2). The impacts constitute the category with the most correct answers, since an average 57.05% of 8th graders and 73.85% of 11th graders gave right answers. The solutions category follows with 43.60% and 56.21% respectively. In contrast the students gave fewer correct answers regarding causes (33.68% - 43.35%). For both causes (31.50% - 22.43%) and solutions (30.72% - 23.40%) the percentage of participants who did not reply is remarkable. It should be noted that although the 11th graders seemed to be much better informed, in fact the general trends, i.e. the relative percentages of right, wrong and no-replies persisted in all three categories, irrespective of the grade.

Students seemed to be more familiar with impacts overall, while their ideas about the solutions and especially the causes of the greenhouse effect were rather murky. This general trend is also visible in the relevant literature (Boyes & Stanisstreet, 2001; Kilinc et al., 2008).

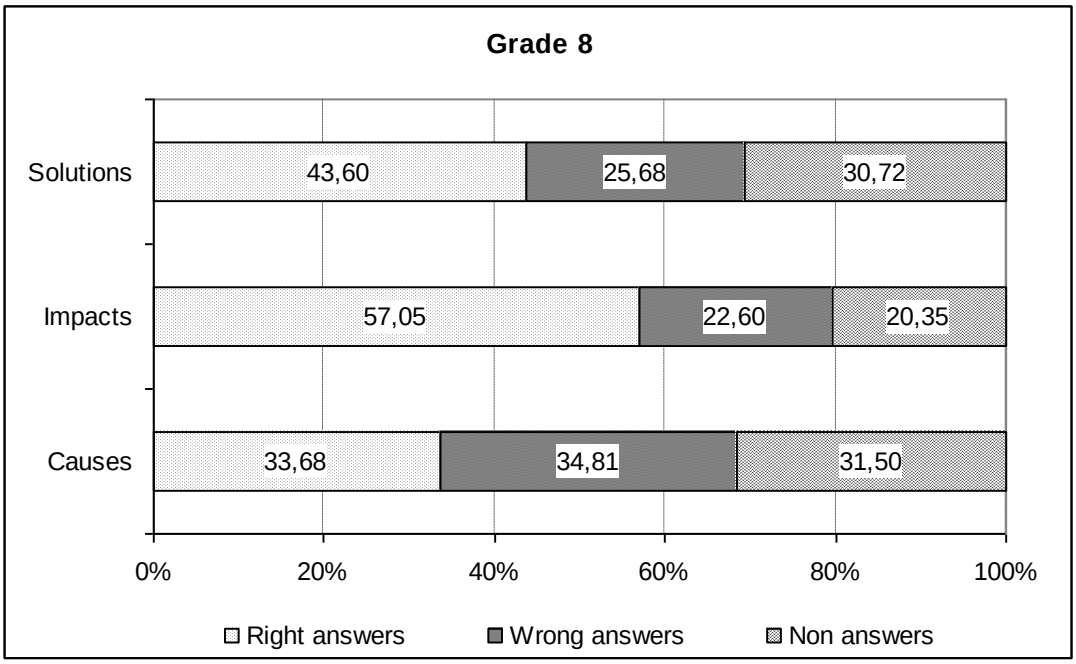

Figure 1. Comparing the answers of 8th graders with regard to causes, impacts and solutions to the greenhouse effect

Information Sources

With regard to the information sources from which students derive information about the greenhouse effect, a large majority of them (81.69% - 87.23%) stated that they use TV, with the school ranking second (55.81% - 46.10%) as a source. Smaller but noteworthy percentages chose other sources such as magazines, discussions with peers and newspapers (Table 3). It should be noted that although the ranking of the sources doesn't change with the grades, it is interesting that from grade 8 to grade 11 the percentage of students choosing the school falls in favour of TV, magazines and discussions with peers.

Kilinc et al. (2008), in contrast to our study, found that Turkish students (age 15-16 years) used the school as the most frequent source of information about global warming (39% on average), followed by television (24%) and other sources (such as newspapers and the internet). Similar trends had already been reported Boyes and Stanisstreet (2001) among UK students (i.e. school 57%, TV 39%). However, the latter study also stressed that the students who reported using TV as a source of information showed greater knowledge about global warming, although they held no fewer misconceptions.

The limited preference of school in relation to other information sources found in the present study, stresses the need for an even more integrated and attractive curriculum with regard to the greenhouse effect and climate change. Although the new curriculum has already incorporated some essential components, it seems that there is much room left for further improvements.

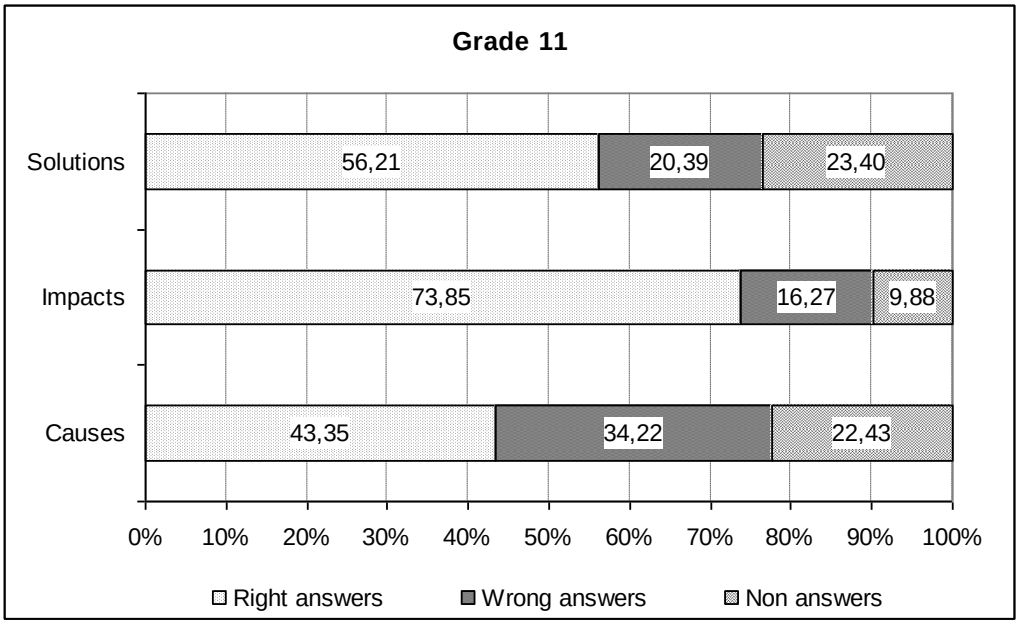

Figure 2. Comparing the answers of 11th graders with regard to the causes, impacts and solutions to the greenhouse effect

Does the Educational Level Influence Students' Ideas?

Using descriptive statistics, a clear trend has been reported regarding the influence of educational level on students' ideas. So we tried to explore this relationship further. Applying chi-square tests it became evident that educational level is indeed an influential factor in students' ideas. This influence of educational level has been reported in previous studies that compared different age groups (Boyes, & Stanisstreet, 2001).

Specifically, for 17 out of 22 statements a statistically significant difference was found ($p < .01$ for df=2) between the ideas expressed by students in grade 8 and grade 11. In fact, the only statements that seemed not to be significantly influenced by this factor were those concerning:

- Causes: the use of hydrogen (st.5), the role of ozone layer depletion (st.6), the role of artificial fertilizers (st.8), the contribution of CO_2 to the creation of life (st.14).
- Solutions: the use of wind energy (st.7).

It is interesting that for all statements of impacts there is a statistically significant difference between the two grades. It should also be noted that four out of five statements that were not influenced significantly belong to the causes category, which accounts for most of the wrong and N/A answers.

Overall, older students were more likely than younger ones to give the right answers to 15 statements. However, the role of educational level seemed to be negative with regard to two statements relating to the contribution of natural gas ($p = .001$) (st.4) and skin cancer as a possible impact of the greenhouse effect ($p = .006$) (st.19). Although students' perceptions about the role of natural gas in relation to their age or educational level have not been explored in the literature, perceptions about the relationship between skin cancer and the greenhouse effect reflect

Table 3. Sources selected by students to learn about the greenhouse effect

Information source	f (%)		
	Gr.8	Gr.11	Total
TV	81.69	87.23	84.19
School	55.81	46.10	51.44
Magazines	32.85	42.91	37.38
Discussions with peers	30.81	38.30	34.19
Newspapers	35.47	32.27	34.03
Specific books	12.21	11.35	11.82

trends that have already been reported. For instance, Boyes and Stanisstreet (1993) reported a slightly diminishing tendency to give right answers (and vice versa) as the educational level or the age of students increases from 12 to 16 years. Boyes et al. (2008) have also reported that the misconception of linking the greenhouse effect with the ozone layer depletion significantly increases with age. In the present study this trend has been confirmed, although not significantly. In short, it is evident that, except for a few specific topics, the role of experience - including school education - that intervenes between *gymnasio* and *lykeio* plays a positive role in cultivating ideas about climate change.

The Role of Gender

There is evidence in the literature to suggest that boys know more than girls about impacts (Boyes & Stanisstreet, 1993) and actions contributing to the reduction of global warming (Daniel et al., 2004). We attempted to examine whether and how gender influences students' ideas. In terms of causes, no statistically significant difference ($p<.05$) was reported between the two sexes. However, with regard to impacts, there are three statements in which girls seemed to be better informed and one statement contradicting this trend. In particular, girls were more likely to believe that global temperature is increasing (st. 17) than boys [χ^2 (4, N = 626) = 9.74, p = .045]. Conversely and surprisingly, girls were more likely to erroneously consider that the polar ice cover is increasing (st. 12) than boys [χ^2 (4, N = 626) = 10.45, p = .034]. However, it is clear again that girls were more likely to "foresee" the intensification of extreme weather events due to climate change (st. 20) than boys [χ^2 (4, N = 626) = 15.93, p = .003] as well as to expect changes in global food production (st. 2) [χ^2 (4, N = 626) = 15.93, p = .003].

Finally, with respect to solutions, only one significant difference was found which converges with the findings of Daniel et al. (2004) suggesting that "males appear better informed" about how to reduce global warming. In particular, boys were more likely to give the right answer to statement 9 (incandescent lamps save energy) than girls [χ^2 (4, N = 626) = 13.62, p = .009].

Summing up, it can be argued that these findings are insufficient to support the argument that gender constitutes an influential factor in shaping secondary school students' ideas about the greenhouse effect and climate change.

Table 4. Ideas of students that have been significantly influenced by participation in EE (for df=4)

Statement	Cat*	True/ False	χ^2	*p*
1. Global sea level	I	T	13.01	0.011
3. Solar energy	C	F	10.20	0.037
5. Hydrogen	C	T	9.76	0.045
6. Ozone layer depletion	C	F	14.93	0.005**
7. Wind energy	S	T	10.49	0.033
11. Carbon dioxide	C	T	20.93	0.000
12. Polar ice cover	I	F	11.30	0.023
17. Global temperature	I	T	10.60	0.031
18. Renewable energy sources	S	F	16.74	0.002
19. Skin cancer	I	F	14.13	0.007**
20. Extreme weather events	I	T	12.41	0.015
22. Public transportation	S	T	13.28	0.010

* Category: C=Causes, I=Impacts, S=Solutions

** Converse influence of EE: the students who have participated in EE are more likely to give the wrong answer.

Does Environmental Education Influence Students' Ideas?

According to the results presented above, education in general seems to influence students' ideas about the greenhouse effect. However, what about the role of EE? This study provided a good opportunity to assess the extent to which EE constitutes a positive factor enriching ideas about the greenhouse effect, since a remarkable percentage of the students (30.99%) had already participated in such programs. In this regard, we applied a series of chi-square tests correlating the 'participation in EE programs' with statements concerning climate change. Table 4 summarizes the statements (in brief titles) in which significant statistical differences were detected.

According to the test results, participation in EE programs seems to be a factor influencing students' ideas about climate change to some extent. Interpreting Table 4, for more than half of the statements (12 out of 22 statements) a statistically significant difference has been reported due to this factor. 4 statements related to causes, 5 statements connected with impacts and 3 statements representing solutions seem to have been significantly influenced. Among them, 10 statements were influenced positively and 2 negatively. In particular, a student who had participated in EE programs was more likely to know that carbon dioxide is a greenhouse gas (st. 11) as well as the role of renewable energy sources, both in general (st. 18) and particularly solar energy (st. 3), hydrogen (st. 5) and wind energy (st. 7), than a student who had never taken part in EE programs. Moreover, such a student was more likely to know some common impacts of the greenhouse effect, such as the rise of the average global temperature (st. 17) and hence the melting of the polar ice cover (st. 12), the rise of the average global sea level (st. 1), the appearance of extreme weather events (st. 20), and that public transport (st. 22) could be a potential solution.

Furthermore we attempted to examine whether there is some association between the above statements and the content of the EE programs in which students had previously taken part. In fact there is no clear evidence of such an association, given that no such program has been reported on the specific topic of the greenhouse effect. However, some subjects imply an indirect relation with this issue (i.e. renewable energy, forests), although further in-depth analysis of the EE program contents would probably lead to clearer results. In brief, we can argue that the partic-

ipation per se in such programs acts decisively on students' ideas even though the core subject may be irrelevant to the greenhouse effect.

On the other hand, a negative correlation between the participation in EE programs and two variables was reported, which should concern members of the EE community. First, it seems to be more likely, through a cause-effect relationship, for those participating in EE to confuse ozone layer depletion (st. 6) with the greenhouse effect. Similarly they were more likely to wrongly believe that the increasing incidence of skin cancer in recent years is due to the greenhouse effect (st. 19). Summing up, although it seems that EE can shed light on interactions among various parameters of this issue, it is less likely that EE can eliminate a previous strong misconception.

Cluster Analysis

Beyond exploring students' basic ideas about the greenhouse effect, we attempted to demonstrate whether there are sub-groups in the sample presenting similar ideas; in other words, whether significant percentages of students with similar characteristics have an overall tendency to answer certain statements in the same way. Such a classification was achieved through cluster analysis. What this technique can offer is:

(a) To reveal student characteristics that seem to play a crucial role in the way they answer particular statements.
(b) To reveal set(s) of statements that are very likely to be answered in the same way (i.e. rightly or wrongly). In this way possible models of thought that connect the issues represented in these statements may emerge. Such models could further be associated with specific categories of students with particular sets of characteristics.

Cluster analysis produced four groups (Figure 3) comprising: 41.85% (Cluster 1), 25.24% (Cluster 2), 25.88% (Cluster 3) and 7.03% (Cluster 4) of students respectively. Here we emphasize the most important and statistically significant findings. Briefly, Cluster 1 is mainly characterized by many correct answers, the students in Clusters 2 and 4 did not answer ('N/A') many statements, while those in Cluster 3 gave relatively many wrong answers.

Specifically, the first cluster consisted mainly of students who: were in grade 11, had participated in EE programs, lived and studied in an urban region, and were informed about environmental issues mainly by magazines. Although a large proportion of correct answers were reported, the members of this group erroneously believed that skin cancer is due to the greenhouse effect. It was also very likely for these students to confuse the greenhouse effect with ozone layer depletion as well as to consider that natural gas does not contribute to the greenhouse effect. Apart from these misconceptions, once again the positive role of both the educational level and participation in EE programs was reflected in this cluster. In addition, the systematic error of associating the greenhouse effect with skin cancer, made mainly by older students rather than younger ones, was also confirmed.

The members of the second cluster were students both of grades 8 and 11, who systematically didn't answer at least half the statements and were informed about environmental issues mainly by the TV. It is quite interesting that they were likely to avoid answering several statements representing solutions and especially causes. The only statement representing impacts that was likely not to be answered was about skin cancer (st. 19).

The third cluster included predominantly *gymnasio* (grade 8) students who had not been involved in EE programs and lived and studied in a rural area. They were very likely to give incorrect answers to at least half the statements in all three categories. Comparing the first and the

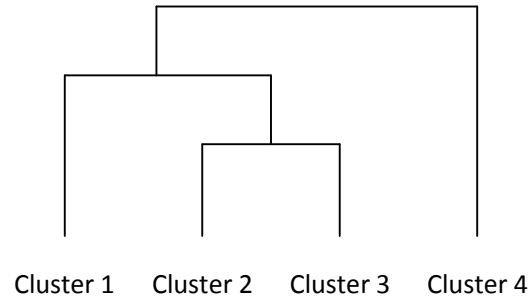

Figure 3. The cluster analysis diagram

third clusters, although the educational level seems to play the most essential role, place of residence as well as participation in EE programs seem also to be influential factors.

Finally, the fourth cluster, which was the smallest one, consisted mainly of *gymnasio* (grade 8) students who were very likely to avoid answering almost all statements. However, the statement with the fewest answers refer to impacts and (less so) to solutions, in contrast to the second cluster in which the N/As were found mainly in statements about causes.

Discussion - Conclusion

Climate change certainly constitutes an important topic for the contemporary school and EE provides teachers and students with the most appropriate educational tools and approaches enabling them to investigate the various parameters of this issue. The curricula of many countries, including Greece, have already incorporated the issues of the greenhouse effect and climate change, while both international organizations and the mass media have widely disseminated this crucial global issue. Thus, students are expected to hold a variety of relevant ideas. The present study examined the ideas of Greek secondary school students of grades 8 and 11 living in an archipelago of islands in the southeastern corner of Greece.

It should first be stressed that a clear difference between students of grade 8 and grade 11 was found. Eleventh graders seem to be much better informed than eighth graders regarding causes, impacts and possible solutions to the greenhouse effect. The overall picture of the results, however, suggests that despite the general improvement in students' knowledge due to their educational level, several trends persist irrespective of grade. Not surprisingly, such a trend is the misconception that is usually reported in the literature and links the greenhouse effect with the ozone layer depletion in a simple cause-effect relationship, together with skin cancer. It is also interesting that this misconception not only persists but actually increases as the educational level progresses. With regard to the categories of the different statements, another remarkable trend has been revealed. Although students have quite clear ideas about impacts, they seem to be rather confused about solutions and especially causes. Quite similar trends have been reported in the literature even though in previous studies the difference between the knowledge level of causes and the other two categories was not as wide (Boyes, & Stanisstreet, 1993; Boyes & Stanisstreet, 2001; Kilinc et al., 2008).

The high percentages reported on the impacts category may be due to the logical sequence of the most of these impacts. Such a sequence is even more apparent in the case of the physical

consequences of global warming (Kilinc et al., 2008). Although the mechanism of the greenhouse effect is neither simple nor linear, it seems to be quite easy even for younger students to perceive that as temperature increases, extreme weather phenomena may intensify, the polar ice cap will probably melt and the sea level is likely to rise. In the literature such impacts have already been characterized as 'well-known' (Boyes, & Stanisstreet, 1992; Boyes, & Stanisstreet, 1993). In contrast, our findings suggest that it is quite difficult for students to recognize some of the basic factors responsible for the exacerbation of the greenhouse effect, especially those that presume specific scientific knowledge and for which there is no visible sequence. For instance, it is not obvious that artificial fertilizers release nitrous oxide. This reason can also partly explain the students' difficulty with regard to potential solutions.

The sources of information that students select might also be a crucial factor. An interesting finding in this regard was the dominant role of television, which in Greece focuses more on the impacts of the greenhouse effect, especially when disastrous events occur, rather than analyzing the causes and the solutions to mitigate this issue. In contrast to the studies (Boyes & Stanisstreet, 2001; Kilinc et al., 2008) in which students seem to gain information primarily from school, in the present study the latter is surpassed by television. Both the one-dimensional approach and the dominance of TV over the school as an information source should concern the educational community.

With regard to preference for information sources, although the new curriculum in Greece has incorporated the greenhouse effect in diverse ways, the contemporary school should offer students more attractive materials than textbooks from which to learn about the greenhouse effect. For instance, the use of experiential learning and multimedia applications could enhance the influence of school learning. Moreover a multidimensional and in-depth approach to the greenhouse effect is needed. In contrast to the one-dimensional television approach, the school can provide students with the appropriate context for an integrated analysis. Such an analysis allows students to acquire and construct the scientific knowledge needed, while at the same time the root causes of the issue can be explored, including the social, economic and political aspects (e.g. the model of economic development, consumption patterns). Through such an approach, effective individual and collective solutions to environmental issues can be revealed and understood.

Within the context of such an integrated analysis, the incorporation of the local dimensions of the greenhouse effect would be of high importance. However, according to the results, students have difficulty in correlating the greenhouse effect with solutions that are strongly associated with the local environment. In particular, it was rather surprising that students could not clearly identify renewable energy sources as potential solutions, although their islands belong to an especially privileged region in terms of solar and wind energy potential. By making such a connection it is more likely for local communities to value green energy and therefore to support the use of renewable energy sources in practice.

The findings summarized above should be taken into account by the educational community so that the greenhouse effect can be taught more effectively. In addition to the need for a more appropriate learning approach to this issue in the curriculum, the extra-curricular EE programs could play a crucial role, providing the context for an in-depth exploration of the root causes and local implications of the greenhouse effect. These programs also allow students to investigate potential solutions, and can further influence local communities to become actively involved in the amelioration of this issue. This particular finding suggests that if such programs gave more emphasis to the issue, students' ideas could further improve.

The present study attempted to investigate students' ideas regarding the causes, impacts and solutions to the greenhouse effect, incorporating some dimensions of its basic socio-political aspects. Having reported the main trends, there is room for further in-depth research targeting on

particular issues, such as to explain students' confusion with regard to causes. Future research should also shed light on possible associations between teachers' and students' ideas. Although there are plenty of studies that examine teachers' and students' ideas separately, it would be very interesting to correlate these two different but interrelated groups. In addition, more emphasis should be given to the relationship between students' ideas and television since its role in the formation of relevant ideas is evidently crucial.

References

Andersson, B., & Wallin, A. (2000). Students' Understanding of the Greenhouse Effect, the Societal Consequences of Reducing CO_2 Emissions and the Problem of Ozone Layer Depletion. *Journal of Research in Science Teaching, 37*(10), 1096-1111.

Batterham, D., Stanisstreet, M., & Boyes, E. (1996). Kids, cars and conservation: children's ideas about the environmental impact of motor vehicles. *International Journal of Science Education, 18*(3), 347-354.

Boyes, E., & Stanisstreet, M. (1992). Students' perceptions of global warming'. *International Journal of Environmental Studies, 42*(4), 287-300.

Boyes, E., & Stanisstreet, M. (1993). The 'Greenhouse Effect': children's perceptions of causes, consequences and cures. *International Journal of Science Education, 15*(5), 531-552.

Boyes, E., & Stanisstreet, M. (1994). The ideas of secondary school children concerning ozone layer damage. *Global Environmental Change, 4*(4), 311-324.

Boyes, E., & Stanisstreet, M. (1997a). The Environmental Impact of Cars: children's ideas and reasoning. *Environmental Education Research, 3*(3), 269-282.

Boyes, E., & Stanisstreet, M. (1997b). Children's models of understanding of two major global environmental issues (ozone layer and greenhouse effect). *Research in Science & Technological Education, 15*(1), 19-28.

Boyes, E., & Stanisstreet, M. (1998). High School Students' Perceptions of How Major Global Environmental Effects Might Cause Skin Cancer. *The Journal of Environmental Education, 29*(2), 31-36.

Boyes, E., & Stanisstreet, M. (2001). Plus ça change, plus c'est la même chose? School students' ideas about the "greenhouse effect" a decade on. *Canadian Journal of Environmental Education, 6*, 77-101.

Boyes, E., Chuckran, D., & Stanisstreet, M. (1993). How do high school students perceive global climatic change: What are its manifestations? What are its origins? What corrective action can be taken?. *Journal of Science Education and Technology, 2*(4), 541-557.

Boyes, E., Stanisstreet, M., & Spiliotopoulou-Papantoniou, V. (1999). The ideas of Greek high School students about the "ozone layer". *Science Education, 83*(6), 724-737.

Boyes, E., Stanisstreet, M., & Yongling, Z. (2008). Combating global warming: the ideas of high school students in the growing economy of South East China. *International Journal of Environmental Studies, 65*(2), 233-245.

Christidou, V., & Koulaidis, V. (1996). Children's models of the ozone layer and ozone depletion. *Research in Science Education, 26*(4), 421-436.

Daniel, B., Stanisstreet, M., & Boyes, E. (2004). How can we best reduce global warming? School students' ideas and misconceptions. *International Journal of Environmental Studies, 61*(2), 211-222.

Devine-Wright, P. (2003). A cross-national, comparative analysis of public understanding of, and attitudes toward nuclear, renewable, and fossil-fuel energy sources. Proceedings of the 3rd conference of the EPUK (Environmental Psychology in the UK) network: Crossing Boundaries – The Value of Interdisciplinary Research, 2003; 160-173.

Devine-Wright, P., Devine-Wright, H., & Fleming, P. (2004). Situational influences upon children's beliefs about global warming and energy. *Environmental Education Research, 10*(4), 493-506.

Fischer, B. (1998). *New Zealand students' appreciation of the greenhouse effect and the ozone hole*. Retrieved March 20, 2010, from http://www.brian.fisher.btinternet.co.uk/

Flynn, R., Bellaby, P., & Ricci, M. (2005, January 28-29). *Risk perception of an emergent technology: the case of hydrogen energy*. Paper presented at the ESRC Social Contexts and Responses to Risk Network Conference - 'Learning about Risk', University of Kent, Canterbury.

Francis, C., Boyes, E., Qualter, A., & Stanisstreet, M. (1993). Ideas of elementary students about reducing the "greenhouse effect". *Science Education, 77*(4), 375-392.

Hansen, P.J.K. (2010). Knowledge about the greenhouse effect and the effects of the ozone layer among Norwegian pupils finishing compulsory education in 1989, 1993, and 2005 - what now?. *International Journal of Science Education, 32*(3), 397-419.

Intergovernmental Panel on Climate Change. (2007a). *Climate Change 2007: Synthesis Report*. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Core Writing Team: R.K. Pachauri and A. Reisinger (eds.). IPCC, Geneva, Switzerland. Retrieved April 12, 2010, from http://www.ipcc.ch/

Intergovernmental Panel on Climate Change. (2007b). *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Retrieved April 12, 2010, from http://www.ipcc.ch/

Jeffries, H., Stanisstreet, M., & Boyes, E. (2001). Knowledge about the 'greenhouse effect': have college students improved?. *Research in Science & Technological Education, 19*(2), 205-221.

Kilinç, A., Stanisstreet, M., & Boyes, E. (2008). Turkish students' ideas about global warming. *International Journal of Environmental & Science Education, 3*(2), 89-98.

Koulaidis, V., & Christidou, V. (1999). Models of students' thinking concerning the greenhouse effect and teaching implications. *Science Education, 83*(5), 559-576.

Lesson, E., Stanisstreet, M., & Boyes, E. (1997). Children's ideas about the environmental impact of cars: a cross age study. *International Journal of Environmental Studies, 52*(1), 89-103.

Liarakou G., & Flogaitis E. (2007). *From environmental education to education for sustainable development: Issues, trends and proposals*. Athens: Nissos Publications.

Liarakou, G., Gavrilakis, C., & Flouri, E. (2009). Secondary school teachers' knowledge and attitudes Towards renewable energy sources. *Journal of Science Education and Technology, 18*(2), 120-129.

Mason, L., & Santi, M. (1998). Discussing the greenhouse effect: children's collaborative discourse reasoning and conceptual change. *Environmental Education Research, 4*(1), 67-85.

Meadows. G., & Wiesenmayer, R.L. (1999). Identifying and addressing students' alternative conceptions of the causes of global warming: The need for cognitive conflict. *Journal of Science Education and Technology, 8*(3), 235-239.

Michail, S., Stamou, A.G., & Stamou, G.P. (2007). Greek primary school teachers' understanding of current environmental issues: An exploration of their environmental knowledge and images of nature. *Science Education, 91*(2), 244-259.

Papageorgiou, G., & Tsiropoulou, S. (2004). The impact of experiments on students' knowledge and explanation of significant aspects of the greenhouse effect. *Journal of Science Education, 5*(1), 28-33.

Pruneau, D., Gravel, H., Bourque, W. & Langis, J. (2003). Experimentation with a socioconstructivist process for climate change education. *Environmental Education Research, 9*(4), 429-446.

Pruneau, D., Liboiron, L., Vrain, E., Gravel, H., Bourque, W., & Langis, J. (2001). People's ideas about climate change: A source of inspiration for the creation of educational programs. *Canadian Journal of Environmental Education, 6*, 121-138.

Rye, J.A., Rubba, P.A., & Wiesenmayer, R.L. (1997). An investigation of middle school students' alternative conceptions of global warming'. *International Journal of Science Education, 19*(5), 527-551.

Shepardson, D.P., Niyogi, D., Soyoung, C., & Charusombat, U. (2009). Seventh grade students' conceptions of global warming and climate change. *Environmental Education Research, 15*(5), 549-570.

Summers, M., Kruger, C., Childs, A., & Mant, J. (2000). Primary school teachers' understanding of environmental issues: An interview study. *Environmental Education Research, 6*(4), 293-312.

United Nations Environment Programme / United Nations Framework Convention on Climate Change. [UNEP/UNFCCC] (2002). *Climate Change: Information Kit*. Retrieved April 12, 2010,from http://unfccc.int/essential_background/background_publications_htmlpdf/items/2625.php

Authors

Georgia Liarakou is an Assistant Professor at the Pedagogical Department of Primary Education, University of the Aegean, Greece. She teaches Environmental Education and Education for Sustainable Development. Email: Liarakou@rhodes.aegean.gr

Ilias Athanasiadis is an Associate Professor at the Pedagogical Department of Primary Education, University of the Aegean, Greece. He teaches Social Research Methods. Email: athanasiadis@rhodes.aegean.gr

Costas Gavrilakis, PhD, is a researcher of Environmental Education and Education for Sustainable Development at the University of the Aegean, Greece. **Correspondence:** University of the Aegean, University Hill, 81100 Mytilene, Greece. E-mail: cgav@aegean.gr

Yunan lise öğrencileri iklim değişikliği konusunda neye inanıyorlar?

Bu çalışmanın amacı liseli Yunan öğrencilerin (8-11 sınıflar) sera etkisi ve iklim değişikliği konusunda neye inandıklarını araştırmaktır. 626 öğrenci, bu küresel çevresel konu ile ilgili nedenleri, etkileri ve çözümleri içeren ifadelerin bulunduğu bir kapalı form anketi tamamlamışlardır. Eğitim seviyesi, cinsiyet ve müfredat dışı aktivitelere önceden katılma gibi üç faktörün öğrencilerin düşüncelerine olası etkisi araştırıldı. Sonuçlar, literatürde bulunan ozon tabakasının incelmesi ve sera etkisindeki neden–sonuç ilişkisindeki gibi bazı kavram yanılgılarının eğitim seviyesinden bağımsız biçimde var olmasına rağmen onbirinci sınıf öğrencilerinin sekizinci sınıf öğrencilerinden daha fazla bilgilendiğini göstermiştir. Öğrenciler genelde etkiye ilişkin düşüncelerinde açık olmasına rağmen çözümler ve nedene ilişkin olarak biraz karışıklıklara sahipti. Bu eğilimlerin olası açıklamaları arasında, mantıksal dizin ve fiziksel sonuçlar ve bazı bilimsel bilgilerin öğrencilerin nedenleri kavramasındaki zorluklar vurgulandı. İlaveten bilgi kaynaklarının rolü, özellikle baskın bir kaynak olarak televizyon tartışıldı. Sonuçta öğrencilerin düşüncelerini olumlu etkilemesi nedeniyle çevresel eğitim programlarına katılım kritik bir faktör olarak görünüyor.

Anahtar kelimeler: iklim değişikliği, sera etkisi, çevre eğitimi, Yunanistan, lise öğrencilerinin düşünceleri