

STUDENTS' IDEAS ABOUT GLOBAL WARMING: A COMPARATIVE STUDY BETWEEN PORTUGUESE AND SPANISH PRE-SERVICE TEACHERS

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This study aimed to verify the knowledge of 149 Pre-Service teachers (91 from a Portuguese institution and 58 from a Spanish one) about global warming, a subject that is approached in their courses and that they will have to teach in the future, since it is part of the Primary school curricula in both countries. For this purpose, a questionnaire was administered at the beginning of the current school year, after the subject was included in a curricular unit dealing with environmental issues in the last school year, in both institutions. The questionnaire included several open questions related to the causes and the consequences of global warming. Due to space limitations, only the results of the following three questions are presented in this paper: 1) How does the use of fossil fuel contribute to global warming? 2) How does the emission of CFCs and other equivalent gases contribute to global warming? 3) How does deforestation contribute to global warming? The answers were classified based on their correctness, from a defined standard response. The Spanish students performed a little better than the Portuguese ones in the first two questions and the reverse occurred with the third question. However, in total, less than 40% of the students were able to answer questions 1 and 3 correctly, and less than 10% question 2. Several misconceptions were revealed by the students, who confused global warming with the ozone layer depletion or revealed wrong ideas about the photosynthetic process, just to mention two of the most frequent mistakes. The results suggest that some improvements in dealing with global warming in teacher training courses are necessary, through the design of activities that include, for instance, the deconstruction of some of the ideas expressed by the students in the present and other similar studies.

Keywords: Pre-service teachers, Global warming, Misconceptions.

INTRODUCTION

Global warming has increased in recent decades due to anthropogenic activities. Among several of the main gases which are responsible for this phenomenon, carbon dioxide is perhaps the best known. Its concentration in the atmosphere has increased from 280 parts per million (ppm) before the Industrial Revolution, to 400 ppm, a value 40% higher in a period of two and a half centuries (Wang, Ge, Wang & Chen, 2014). Other gases implicated in global warming, such as methane (CH₄), chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride, nitrous oxide, ozone at tropospheric altitudes, and water vapour, are often less mentioned but their impact is also significant. In fact, it is not only the percentage of a certain gas in the atmosphere that counts in the process of global warming, but also its effectiveness at absorbing infrared radiation, the Global Warming Potential (GWP). Compared to the carbon dioxide potential to trap heat, methane has a GWP of 21, nitrous oxide a GWP of 301 and sulphur hexafluoride a GWP of 23900, just to mention a few gases (Daniel, Stanisstree & Boyes, 2004). But global warming causes can be even more

complex, with a chain of reactions which have the main effect of increasing the Earth's temperature. For instance, tropospheric ozone is responsible for the inhibition of photosynthesis, which causes a decrease of absorption of carbon dioxide by plants (Daniel, Stanisstreet & Boyes, 2004).

Global warming and other environmental problems such as the ozone layer depletion are issues which are present in the curricula of several countries, from primary to higher education, naturally with an increasing degree of complexity. However, these particular phenomena have been misunderstood as to their causes and consequences and are even confounded over the years, even when students take science courses (Reynolds et al. 2010). Several studies with higher or non higher education students have found, for example, the following wrong ideas: i) carbon dioxide is responsible for global warming and also for the depletion of the ozone layer (Huxter, et al., 2015); ii) the ozone hole allows more UV radiation, which causes global warming (Michail, Stamou, & Stamou, 2007; Shepardson et al., 2009; Allen, 2010); iii) carbon dioxide is the only greenhouse gas recognized in global warming (Boyes & Stanisstreet, 1993; Fisher, 1998; Shepardson et al., 2009); iv) the trapping of infrared radiation is badly recognized as the cause of greenhouse effect (Boon, 2010).

It is important to mention that frequently these and other misconceptions are present in students of different degrees or cycles of schooling. For instance, a study promoted in Australia by Bono (2010) found that pre-service teachers and secondary students answered correctly a list of global warming statements with a very low and equivalent percentage (less than 15% in both groups). But the pre-service teachers' results are of a particular concern, since they will have to teach this and other environmental issues to their future pupils.

The present study tried to check the ideas related to global warming in pre-service teachers from two institutions that prepare for teaching in the first six years of schooling (one in Portugal and one in Spain). In the study plans of both courses, students had approached the global warming issue in a curricular unit, during the previous school year. This kind of research is important to assess the efficacy of teacher training preparation and can help to design new approaches to help scientific accuracy. In fact, as quoted by Khalid (2003), when teachers have a poor understanding of some environmental concepts, they can be responsible for misconceptions in their pupils.

METHOD

The sample of the present study involved 91 Portuguese pre-service teachers and 58 Spanish ones, almost all females, and the average age of the groups was, respectively, 24.4 and 22.7 years old. As it was already stated, the students were from two institutions that prepare teachers for the first six years of schooling (children aged from 6 to 12). The institutions were chosen on the basis of their relevance in pre-service teaching courses in both countries and due to the fact that they are the workplaces of the research team. Therefore, the dissemination of the results is facilitated as well as the possibility of making changes in the teaching practice process of global warming.

A questionnaire was administered in both countries in October of the school year of 2016/2017. In the previous school year, the students of both countries studied this issue. In the case of the

Portuguese institution, the global warming issue is included in the syllabus of the curricular unit Earth Sciences; in the Spanish institution it is included in the syllabus of the curricular unit Natural Environment: Physics, Chemistry and their Didactics. The teaching of the global warming issue was confirmed by each of the teachers who are responsible for the curricular units mentioned above.

The questionnaire included several questions distributed by two parts concerning different causes and consequences of global warming. One part related to how pre-service teachers value and understand the impact of livestock production on global warming was already published (see Almeida, García Fernández & Sánchez Emeterio, 2016). Due to space limitations this article is focused on the results related to the following three open questions of the questionnaire:

- 1) How does the use of fossil fuels contribute to global warming?
- 2) How does the emission of CFCs and other equivalent gases contribute to global warming?
- 3) How does deforestation contribute to global warming?

The answers were analyzed for their content and compared with standard correct responses defined as follows:

- 1) The burning of fossil fuels releases carbon dioxide and other gases that trap infrared radiation which dissipates from the surface of the Earth;
- 2) CFCs and other similar compounds are potent molecules which retain the infrared radiation;
- 3) The destruction of trees reduces the amount of photosynthesis, a process that removes carbon dioxide from the atmosphere and stores it in the plants; a common process of deforestation is burning, which releases carbon dioxide.

The answers were classified according to the following criteria: Correct answer; Partially correct answer; Answer not focused on the intended relationship; Answer with correct items but with serious inaccuracies; Incorrect answers; Don't know. To ensure consistent coding, each researcher classified the students' answers and at the end of this process an external consultant helped to find a consensus in a few divergent classifications. Since the results from both countries were quite similar, no inferential statistics was used and only the percentage of the results is presented.

RESULTS

The results, comparing the performance of the students of both countries according to the codification used, are in Table 1.

In the first question, concerning the relationship of fossil fuels with global warming, the percentage of Spanish students who responded correctly was higher (10.3%) comparing to the percentage of the Portuguese ones (5.5%). Even so, the percentage of students with a correct or partially correct answer was, respectively, 41.8% - P and 29.3% - Sp. This means that nearly 60% and 70% of the students of both countries were incapable of establishing the relationship demanded. Also with a high incidence in both groups, 18.7% - P and 32.8% -Sp, were answers that didn't explain the intended relationship.

Table 1. The results in percentage for the students of both countries (P- Portugal and Sp – Spain) according to the codification used: A: Correct answer; B) Partially correct answer; C) Answer not focused on the intended relationship; D) Answer with correct items but with serious inaccuracies; E) Incorrect answers; F) Don't know.

Q	A %		B %		C %		D %		E %		F %	
	P	Sp	P	Sp	P	Sp	P	Sp	P	Sp	P	Sp
1	5.5	10.3	36.3	19.0	18.7	32.8	2.2	1.7	17.6	17.2	19.8	19.0
2	-	5.2	1.1	3.4	13.2	12.1	46.7	36.2	15.4	12.0	22.0	18.0
3	-	-	37.4	25.9	37.4	32.8	4.4	3.5	10.9	15.5	9.9	22.4

In the second question, the results are even worse with only 8.6% of the Spanish students and 1.1% of the Portuguese ones giving a correct or a nearly correct answer. As in the previous question, the role of infrared radiation in the global warming process was not recognized and the students were unable to recognize the ability of CFCs and other similar gases to capture that radiation.

In the third question, the Portuguese students performed a little better. Even so, more than 60% of these students and more than 70% of the Spanish ones could not explain the impact of deforestation on global warming.

Also important to highlight is that nearly one fifth of the students of both countries don't know how to answer the questions, except for question 3 for the Portuguese students where (9.9%) did not know the answer.

For each question we are going to present the answers given by the students of both countries in categories D (answer with correct items but with serious inaccuracies), and E (incorrect answers). This selection highlights the main misconceptions revealed by the students and allows identifying the conceptual mistakes that were more frequent. For this purpose, answers in category C (answer not focused on the intended relationship), are not relevant, since they only included correct statements which do not answer the questions. Even so, a few examples are included in the text for a better understanding of this type of answers.

In the case of question 1, the main wrong ideas are included in Table 2. Several of the incorrect answers or of those with serious inaccuracies show that a high number of students believe that the release of carbon dioxide causes the ozone depletion phenomenon and this, in turn, implies the increase of UV radiation responsible for global warming. This idea is somehow present in other answers but expressed in different ways. This is the case when students highlight the pollution emitted by fossil fuels which increases the ozone layer hole or is responsible for the increase of the temperature. As it is possible to verify, the role of infrared radiation in global warming process is completely absent in the answers of these students. Examples of answers of type C, not included in the table were: "Fuels emit gases that pollute the atmosphere", "The constituents of fossil fuels are harmful to the atmosphere"; or "The constituents of fossil fuels are toxic".

In the case of answers to questions 2, the results were even worse, as it was already expressed at the beginning of the present section. The main wrong ideas are included in Table 3.

Table 2. The incorrect answers for question 1) How does the use of fossil fuels contribute to global warming? revealed by pre-service teachers of both countries (P- Portugal and Sp – Spain), according to the categorization: D - Answer with correct items but with serious inaccuracies; E – Incorrect answers; F – Don't know.

Type of answers	P	Sp
Answer with correct items but containing serious inaccuracies	2 (2.2%)	1 (1.7%)
The burning releases CFCs into the atmosphere, one of the gases responsible for global warming.	1	-
The release of CFCs damages the ozone layer and solar rays enter and increase earth temperature.	1	1
Incorrect answers	16 (17.6%)	10 (17.2%)
The use of fossil fuels destroys the ozone layer that protects us, causing global warming.	5	5
The burning releases CO ₂ and this degrades the ozone layer, which fails to protect the surface from UV radiation causing global warming.	5	-
Fossil fuels emit pollution that increases the ozone layer hole.	-	1
The gases released into the atmosphere favor the production of ozone and maintain the ozone layer in the troposphere.	3	-
Pollution causes the decrease of the ozone layer which in turn causes global warming.	1	1
The extraction and use of fossil fuels cause the emission of gases to the ozone layer, which causes an increase of the temperature.	-	1
Other similiar wrong ideas	2	2
Don't know / No justification	18 (19.8%)	11 (19.0%)

Table 3. The incorrect answers for question 2) How does the emission of CFCs and other equivalent gases contribute to global warming? revealed by pre-service teachers of both countries (P- Portugal and Sp – Spain), according to the categorization: D - Answer with correct items but with serious inaccuracies and E – Incorrect answers; F – Don't know.

Type of answer	P	Sp
Answer with correct items but containing serious inaccuracies	42 (46.7%)	21 (36.2%)
The excessive emission of CFCs and other equivalent compounds destroys the ozone layer, causing global warming.	30	15
The emission of CFCs destroys the ozone layer, allowing ultraviolet radiation to pass through and this causes the greenhouse effect.	12	6
Incorrect answers	14 (15.4%)	7 (12.0%)
CFCs release harmful gases that contribute to global warming.	4	-
The emission of CFCs and other equivalent compounds increase the production of ozone, which favors the absorption of solar radiation and, consequently, global warming.	2	-
CFCs are extremely air pollutant, which contributes to global warming.	5	5
CFCs lead to a decrease in oxygen in the air.	-	2
CFCs release CO ₂ that degrades the ozone layer, which stops protecting the surface from UV radiation and causes global warming.	2	-
CFCs are harmful gases that increase the ozone layer, which prevents the heat from coming out.	1	-
Don't know / No justification	22 (23.1%)	18 (31.0%)

The majority of the students of both countries associated the release of CFCs and other equivalent gases with the depletion of the ozone layer. And this depletion is responsible for the increase of UV radiation, causing global warming. Therefore, they are unable to recognize their important role in capturing infrared radiation.

Other incorrect answers were somehow strange and revealed a mix of ideas that are totally wrong. This is the case of answers like: “CFCs release gases like the carbon dioxide, which is responsible for global warming”; “CFCs are very polluting gases, provoking global warming” or even “CFCs lead to a decrease in oxygen in the air”.

Examples of answers of type C were also present but to a lesser level. Examples of this type of answer were: “The CFCs destroy the ozone layer”; “The CFCs are very dangerous molecules” or “CFCs can be found in the sprays”.

Finally, the performance of the students of both countries in question 3 was a little better. Even so, several mistakes could be identified and are included in Table 4.

Table 4. The incorrect answers for question 3) How does deforestation contribute to global warming? revealed by pre-service teachers of both countries (P- Portugal and Sp – Spain), according to the categorization: D - Answer with correct items but with serious inaccuracies; E – Incorrect answers; F – Don't know.

Type of Answers	P	Sp
Answer with correct items but containing serious inaccuracies	4 (4.4%)	2 (3.4%)
With deforestation, CO ₂ capture is reduced, which destroys the ozone layer.	2	-
It increases CO ₂ concentration and UV capture.	1	-
Trees produce less oxygen, which depletes the ozone layer.	1	2
Incorrect answers	10 (11.0%)	9 (15.5%)
With deforestation, the gases that destroy the ozone layer increase.	2	-
Plants regulate the gases present in the atmosphere through their respiration and deforestation unbalances this process.	1	-
With deforestation the air becomes saturated.	1	-
Forests produce gases that cool the planet.	1	-
Vegetation absorbs water. If water is not absorbed, it becomes standing water.	-	1
Plants provide air and energy.	-	1
Other ideas	5	7
Don't know / No justification	9 (9.9%)	13 (22.4%)

In this question, the students performed a little better. A frequent wrong answer was that “deforestation is responsible for the decrease of oxygen in the atmosphere” and the idea that “with the decrease of trees, the CO₂ is not transformed into O₂”, a misunderstanding of the photosynthesis process. However, the number of correct answers was not so high, since near one third of the students of both countries gave answers of type C. Just a few examples: “Trees have a protective function, beneficial to the planet”; “Without deforestation, there will be less rain”; “As there is no vegetation, solar rays affect the soil more intensely”.

DISCUSSION AND CONCLUSIONS

Several authors support the importance of teaching about global warming, since it is an issue with social and personal relevance that enables the exercise of an active citizenship (Brown, 1992; Bybee, 1993; Shepardson, Niyogi, Choi & Cahrusombat, 2009). In the case of pre-service teachers, it is also important to guarantee a correct scientific learning process due to the fact that these students will be responsible for teaching young students in the near future.

The results of this study show that the understanding of the global warming process by the majority of the students of both countries is incomplete and reveals a lot of incorrect ideas and converges with other studies presented in the introduction section. It seems that several mistakes persist though time in different samples with different ages and from different cultural backgrounds. In fact, the results are quite disturbing, since the students revealed several misconceptions of the issue under discussion, and they confirm the failure of formal education in approaching the issue with good learning results. And it is important to remember that students had a formal teaching unit involving global warming only a few months before the administration of the questionnaire. Several ideas already identified in studies in other countries are also shown in the present results, such as the confusion between global warming and the depletion of the ozone layer, the incapacity to recognize other greenhouse gases beyond carbon dioxide, or the role of infrared radiation on global warming.

Therefore, it seems important to implement a few changes in the learning process of this environmental problem. In fact, consulting the syllabus of the curricular units related to environmental issues in both countries, we realized that global warming was only a tiny part of their content. Thus, one of the main reasons for the failure of the learning process can be the small amount of time dedicated to the issue and, of course, the way it is approached.

To guarantee better learning results, Rebich and Gaubier (2005) quote that the most popular instructional approach to promote conceptual change has the following steps: to identify misconceptions, to present information that causes conflict with previous knowledge, to present contradictory information; and finally to identify conceptual changes. For all these steps you need time, a precious element that is always missing, especially in higher education, but which is fundamental to guarantee the quality of the learning process.

Even so, Guzzetti et al. (1993) claim that this process is not always a guarantee of success. That is why Rebuch and Gaubier (2005) suggest a multiplicity of methods to encourage meaningful learning where the discussion of wrong conceptions can help to promote a cognitive conflict in students' minds, and also suggest that other strategies should be used, like conceptual maps or the discussion of anomalous ideas in a cooperative and shared learning process. In conclusion, the approach to this complex issue seems to need more time and special attention should be given to the teaching methods used in its approach.

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