Assessing pupils' understanding about greenhouse effect in context of problem-based approach in environmental education: a case study from Greece

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Abstract. The greenhouse effect is a process that regulates the temperature of the planet. Students have misunderstandings about the greenhouse effect. The misunderstandings about the greenhouse effect may result from the direct analogy of a greenhouse as a means to maintain the heat by preventing convection and trapping warm air inside. The main research question has to do with the extent that pupils understand the greenhouse effect as an environmental problem. The sample consisted of 18 pupils of a 4th grade Primary school classroom forming case study research. The analysis of answers was mainly based on qualitative grounds, by examining the way pupils express their opinions or beliefs about this specific environmental topic. Students' answers present that they understand enough the greenhouse effect both as a natural process and as environmental problem. They seem to present a lower understanding about its causes, but a mediocre understanding about consequences and interesting suggestions about how to solve it. As far as the use of accurate or scientific words is concerned, the statements seem to be on a low level. In conclusion, it can be supported that problem-based teaching intervention can contribute to pupils' understanding about environmental problems such as the greenhouse effect.

1 Introduction

The greenhouse effect is a natural phenomenon, which is considered to be a particularly complex environmental topic [1]. This phenomenon integrated in the wider topic of climate change, is related to planet temperature regulation. Burning fossil fuels seems to enforce greenhouse effect, increasing the level of dioxide of Carbon in atmosphere, leading to global warming [2]. Even if the greenhouse effect is described by a more simplified way, the complexity of the phenomena that are involved, require particular teaching to be approached effectively, as it is shown in certain research study [3].

In the context of educational research about greenhouse effect, it has been observed that there are difficulties as far as its understanding is concerned. Any misunderstanding or misconception of basic principles concerning both the relative scientific concepts and the correspondent phenomena, such as greenhouse effect, can greatly confuse and obstruct subsequent learning. This is supported to be true especially in the case of climate science [4].

Moreover, as it has been shown in certain study difficulty of understanding may stem from the fact that this phenomenon includes many and complex scientific concepts [5]. Furthermore, in other study it has been considered as significant about difficulty of understanding the fact that this phenomenon includes non-visible and abstract processes [6]. Another reason why greenhouse effect is difficult to be understood is that it has many sides to be approached creating complex questions, while especially in Greece perhaps the economic crisis may be a factor that influence awareness about it as it happens about other environmental topics [7].

There are also enough researches about understanding of greenhouse effect approaching the topic by different ways [10-13]. In other research students seemed to present difficulty discovering the meaning of words leading to result that the students' work present persistence of common misconceptions after learning [2].

Greenhouse effect is a topic that has been examined in PISA in an effort of assessment. In this process, students are asked to determine whether the greenhouse effect is fact or fiction. To explain this scientific phenomenon, they must read an article where two points of view are presented. They are also presented with two graphs and there are two students different conclusion about the way they interpret these graphs. One student concludes from the graphs that the increase in the Earth's average temperature is due to carbon dioxide emission. The other student states that before drawing such a conclusion, other factors need to be considered. Students that participate in PISA assessment, are asked to name a factor related to energy/radiation coming from the sun or a factor related to a natural component such as water vapors or to a pollutant such as exhaust gas [14].

Commending PISA assessment about greenhouse effect, it has been supported that PISA team rejects a model based on simple recall of scientific facts, but in the

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analysis of relative study, these items come close to asking for recall [15].

The complexity of the topic combining with the fact that there is a particular discussion about environmental problems nowadays, enforce necessity for further investigation in educational context, using different ways of approaching this topic. In this study, based on findings of previous relative researches, mainly about the difficulty that teaching this topic presents and pupils' misunderstanding about it, pupils' understanding about greenhouse effect is assessed in the context of a problem-solving approach using various teaching tools that can help to better understanding, utilizing as analysis pupils' answers through a linguistically based tool in content analysis terms, being influenced by assessment that has been conducted in TIMSS and utilizing Bernstein's theory that has been tested in previous research about concepts and phenomena in science education.

2 Methodology

In the context of this paper, there are two sides concerning methodology, the one that refers to teaching method which was selected and applied in the context of an intervention and research methodology that was taken place in order to present the results of this study.

2.1 Teaching Intervention

Environmental education is important in terms of raising individuals who are environmentally sensitive and can offer solutions to environmental problems [16], one of which is greenhouse effect. To approach greenhouse effect in this teaching intervention, problem-based methodology was implemented. Since it is a phenomenon that is presented as an environmental problem, eighteen 4th grade pupils in a primary school were called to be engaged in proper processes in order to approach it as little scientists who have to investigate it and find ways for solution, in problem-solving terms. The pupils who participated in this study were 9 boys and 9 girls coming from different countries (8 Greek pupils, 4 Albanian pupils, 3 Romanian pupils, 2 Bulgarian pupils and 1 Egyptian pupil). These were pupils of a 4th grade class in a Primary School in Athens.

As it has supported by recent work, sample sizes in qualitative research are guided by data adequacy, so an effective sample size is less about numbers and more about the ability of data to provide a rich and nuanced account of the phenomenon studied [17]. The decision for selecting a small sample in the context of the present study, was based on the assertion that samples in qualitative research tend to be small in order to support the depth of case-oriented analysis that is fundamental to this mode of inquiry [18].

This teaching intervention lasted for six weeks. The problem-solving teaching process, as it was implemented in the context of this study, is presented in the figure
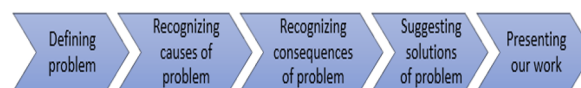
below

Fig.1. Problem-solving teaching process.

Following problem solving methodology defining problem, its analysis (causes and consequences), presenting proposals for solution of problem was implemented in order to lead to better pupils understanding about greenhouse effect. In the context of defining pupils' ideas were elicited as constructivist theory suggests in order to create a clear image of the problem leading to changes of potential misconception about this problem [19], aiming to understand the meanings constructed by students participating in context-specific activities using language [12]. The existence of misconceptions was evidenced by previous researches as well. As far as analysis of problem is concerned and based on defining problem, which was preceded, there was a focus especially on causes and consequences of this problem. Acting in such a way, can lead to a more complete approach of problem. Finally, after the previous stages, an effort to propose potential solution of the problem was carried out.

During teaching intervention various teaching tools were used. ICT tools such as simulations, - in relevant study it was shown that scaffolding of procedural information during the simulation enabled pupils to modify their provisional models of the greenhouse effect by appropriating and utilizing the tools presented in the simulation - and other visual materials, which has been used about inquiry of greenhouse effect in research study [20] were integrated in relative activities in order to visualize the greenhouse effect.

As it has been utilized in previous study, the PhET greenhouse simulation was used in this study as well. This simulation targets to facilitate inquiry about the behavior of different types of radiation, representing photons with yellow balls for sunlight and red balls for infrared radiation. The interaction, absorption and emission of radiation with gases and the Earth's surface are emphasized in the simulation. In this simulation there are various factors that can be examined in order to study greenhouse effect in a more complete way, as can be visualized in the figure below
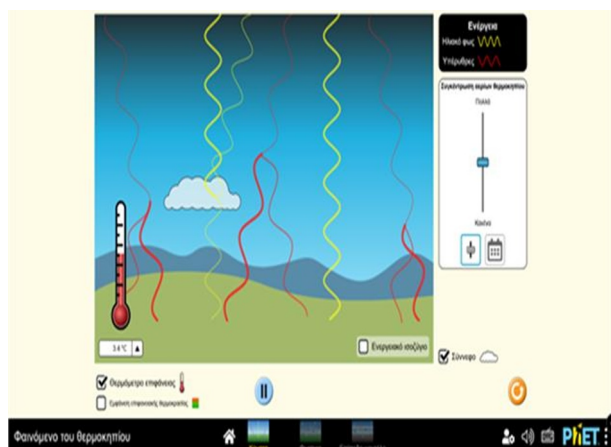
Fig.2. The Phet greenhouse effect simulation, utilized in this intervention.

Moreover, drawings as mediating tools were used in a constructivist perspective in context of eliciting pupils' ideas about greenhouse effect. Drawing has been used in other study in which it was supported that drawings can provide pupils with the means of becoming aware of their own conceptions of the greenhouse effect, clouds and the atmosphere [21], while in another study, it is shown that drawings to assist students to articulate, reflect on and improve their understanding of global warming. In particular, instruction based on their visualization can help students to consider and discuss various sources of greenhouse gases in relation to intensified warming of the earth's surface rather than focusing on the paths of radiation [6].

2.2 Research methodology

The main research question has to do with the extent that pupils understand totally greenhouse effect (e.g., the process of its formation, its causes, consequences). The sample consisted of 18 pupils of a 4th grade Primary school classroom in environmental education, forming case study research. The assessment of pupils' understanding about greenhouse effect, took place by providing them worksheet that could test their understanding. The analysis of answers was based on qualitative grounds, by examining the way pupils express their opinions or beliefs about specific topics concerning greenhouse effect, being a particular case study.

The content analysis is considered to be the most appropriate method of analyzing written contents of documents such as answers in worksheets, grounding on qualitative research. Content analysis has been used in other research as well to present students' responses resulting in the identification of students' concepts and this process was inductive in nature [12].

As far as the instrument used for data analysis is concerned, we were mostly influenced by research efforts focus on the micro level of classroom (Morais, 2002) [22]. As far as the coding classification form was mainly influenced by TIMSS which is an international study of assessment, especially its part referred to pupils' understanding.

The assessment of this process, took place though the construction of appropriate worksheets, concerning greenhouse effect as environmental problem. The questions required short answers by which pupils had to show to what extent they had understood scientific concepts, how they expressed their views and to what extent they have appropriated the elaborate linguistic code that science as discipline uses.

According to Bernstein theory, pedagogic discourse is transmitted through a specific code that integrates specialized contexts (e.g., science classroom contexts) and the selection and production of appropriate texts to these contexts [23]. Any textual production in a given context depends on the acquisition of the specific coding orientation to it. This means that learners should have acquired the recognition rules (i.e., they should be able to recognize the context) and also the realization rules to produce the respective legitimate text, as well.

The instrument used for data analysis is based on content analysis method, having as unit of analysis pupils' text when they answer the questions. As for the coding, classification form was mainly influenced by TIMSS, which is a international assessment that monitor trends in student achievement in cognitive objects including science that concerns phenomena such as greenhouse effect and the categories formed for data analysis concerned first of all the extent to which pupils accessed to the scientific content and secondly in what way they appropriated science language (e.g., using scientific terms in the appropriate context) [24].

Taking into account Bernstein's view in combination to TIMSS assessment, we constructed the following instrument, which has been used in previous research study [25] for assessing pupils in science teaching, adapting it in order to assess pupils' understanding of greenhouse effect for analyzing pupils' answers when they completed the corresponding worksheets, by focusing on the categorization below:

Table 1. Formality tool analysis.

	Linguistic code Formality levels		
Formality indicators	**High**	**Medium**	**Low**
Use of scientific concepts concerning greenhouse effect	High frequency of scientific concepts	Medium frequency of scientific concepts	Low frequency of scientific concepts
Accuracy of sentences concerning greenhouse effect	High accuracy of sentences	Medium accuracy of sentences	Low accuracy of sentences
Cognitive understanding of teaching content	High degree of understanding	Medium degree of understanding	Low degree of understanding

As far as the instrument is concerned, it was constituted by two parts that were interrelated: formality indicators and linguistic code formality levels. About the indicators, we used the first one to examine how

frequently pupils use scientific concepts when they had to answer to questions of a worksheet. The second part of instrument is constituted by three levels that code linguistically the formality that has been demonstrated by the indicators. These levels are: high, medium and low, each of which refers to the corresponding level of each indicator.

The first indicator tries to show the extent to which pupils have been familiarized with the complex scientific concepts, in a context that transmit science to school science, and have managed to reach the scientific meaning about greenhouse effect. Particularly, the low frequency concerns the use of 0-1 scientific concepts, the medium frequency concerns the use of 2-5 concepts and the high frequency refers to the use of more than 5 concepts.

By using the second indicator, we tried to show how precise pupils are in forming sentences for scientific concepts and phenomena. Accuracy is one of the most significant abilities that one should have when negotiates about issues concerning scientific phenomena, such as greenhouse effect. Accuracy can be examined in relation to how close a statement approaches what science mentions about the certain topic.

Finally, the use of the third indicator had as target to find to what extent pupils have understood the content of environmental teaching, especially about greenhouse effect. Understanding is what is required by teaching that shows if pupils have really known what they have been taught about this certain topic, when express their written statements.

3 Results and Discussion

The results of this study show that pupils have understood enough about the greenhouse effect both as a natural process and as environmental problem. About the use of scientific concepts in their statements, they mention sun rays which have a certain orientation but also underline the crucial role of gases. The expressions about greenhouse effect show a simplified approach of the problem without more analytical description. Almost all pupils use sentences like "*sun rays get in earth but some gases do not permit rays to get out*", showing that there is not a very accurate meaning about the problem and the only scientific concepts that are used are: ***sun rays and gases***.

As far as the causes of greenhouse effect is concerned, pupils consider that human factor is the main cause for this environmental problem. Especially, they express different sides to justify this conclusion by sentences like "*people pollute environment*", "*the factories emit gases*", "*car emit exhaust gases*", "*people cut down the trees*". There is not a really accurate approach using scientific concepts except exhaust gases, but there is an effort to reach understanding about the causes orientated to human activities which enforce greenhouse effect.

About consequences of greenhouse effect, pupils give some different views such as "*increase of temperature*", "*lack of water*", "*diseases*", "*ice melting*". These views show that there is a multi-level approach of consequences. Increase of temperature can be seen as a simplified

expression of global warmth, while the other views (e.g., *lack of water or ice melting*) consist significant environmental topic even if these topics are approached not as deeply as the accuracy of scientific approach suggest. The view concerning *diseases* is probably a more anthropocentric approach. From the above remarks, it is obvious that mediocre understanding about consequences of greenhouse effect has been achieved, showing a medium degree of understanding according to the tool which is used for analysis.

Finally, there was potentiality to express probable proposals for solving greenhouse effect. The answers were mainly divided in two separate sides. The one concerning that human activity should be taken place as it is needed in order not to enforce this environmental problem, suggesting limiting of certain human activities. There were examples about this such as less use of cars or reducing pollution. This proposal concern reducing negative effects of human activities. On the other hand, it was proposed to be more trees, which show a positive perspective of solving greenhouse effect.

Considering this study in relation to other previous researches in a discussion context, there are significant observations that can be taken into account. In this research pupils mention sun rays that get in earth. Similar views were found in research, where students support that "*sun rays . . . try to escape the atmosphere but are bounced back to Earth. The CO2 levels in the atmosphere are high enough to let rays in, but not out*" presenting more elaborate linguistic code in relation to the present study [12]. In other research students identified CO2, CH4, N2O as greenhouse gasses but did not identify and recognize other greenhouse gases such as water vapor. Differences can be explained by the age of pupils (in this study 4th grade of primary school aged 10 years old, while in the other the students' age range, which was 15-16 years) [1].

As far as causes of greenhouse effect in this study there is orientation to human factor about it without accurate statement concerning use of scientific concepts. In other research the greenhouse effect and ozone layer depletion, have been emphasized, and converging to these, are the various causes offered by children. Some of these causes we would call 'external', whereas a number of them emanate from the other global environmental issue. [10].

Another point that it is shown in this study was the difficulty of pupils to understand completely greenhouse effect. In previous research it was observed pupils have difficulty in understanding explanations of the greenhouse effect and the depletion of the ozone layer [2], while in other research this finding was justified due to the fact that greenhouse effect is an invisible phenomenon that cannot be directly observed and hard to understand [1].

Moreover, similarity was observed about the teaching tools that were utilized in this study in relation with previous ones. The use of simulations, especially Phet greenhouse effect simulation has been used presenting interesting results [3]. Drawings also has been used previously as well in the context of a constructivist approach of teaching [12]. In this study, drawings were used mainly to elicit pupils' misconceptions. In all studies

both simulations and drawings seem to help in promoting pupils' understanding.

One of the differences between this study in relation to previous research, was first of all the age of students. There was no other research conducted in classroom of pupils aged 10 years old. In this point there should be underlined the fact that pupils who participated in this study, have not been familiarized with scientific phenomena and scientific concepts since they have not learned science as a separate cognitive object but they only have studied not deeply some topics of environmental interest.

Secondly, in this study teaching intervention based on problem solving method has been chosen. In other case a constructivist perspective guided the study [12], while another study was inspired by constructivist epistemology adopting Model of Educational Reconstruction [13]. In this study, the utilization of constructivism concerned mainly the elicitation of students' ideas and misconception about greenhouse effect, because it could help to transform them to statements which are more familiar with scientific view about it.

As far as the focus on Greek education, it has been seemed that research about this topic is limited. Nevertheless, there is reported on the ideas of Greek primary school students (11-12 years old) and analyzed 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 [11], which was likewise reported in the study conducted by Boyes, Stanisstreet and Spiliotopoulou-Papantoniou (1999) who investigated perceptions of Greek school students (age 11-16 years) about the ozone layer [26]. Moreover, Papageorgiou and Tsiropoulou (2004) focusing on the impact of teachers supported that " 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 [27].

Focusing on Greek researches these studies differ from the present research, first of all about the age of pupils who participated but also the methodological way of approaching this topic both about teaching intervention and methodologic analysis, since there is no other similar study where pupils that participate were younger than 11 years old, while in this study were about 10 years old pupils of 4th grade primary school. In present study pupils understanding was approached in the context of problem-based teaching, through content analysis of answers in worksheet, while in other researches in Greece mainly interviews were conducted.

Comparing this study with other similar conducting in other countries, there is similarity about the difficulty that pupils face when they deal with complex concepts and procedure such as greenhouse effect. For instance, in a study taken place in Sweden [2], which was a case study as well, pupils experienced difficulty in distinguishing between the different meanings attached to individual concepts in their theoretical and practical contexts. In another study which conducted 2 in one of urban educational areas in West Java involved primary school students aged 10-12, it was found that students' conceptions of greenhouse effect could be diagnosed by sub-microscopic representation, both verbally and visually [9]. The difference about the sample (number and age of pupils), lead to a different view of the topic. For instance, in a study qualitative data were collected from 51 secondary students from three different schools in the Midwest, USA, reflecting different degrees of sophistication of students' conceptions about the greenhouse effect, global warming, and climate change. [12]. The present study, although the small number of pupils (which lead to assess in the context of a qualitative case study), is the only one that was conducted in class with 4th grade pupils, younger than similar studies from other countries, which can lead to interesting and for first time research results, since there have been no other similar research where so young pupils participate. Moreover, in this study, the synthesis of participants concerning their gender and the country they come from, gives another dimension in the context of a qualitative case study.

4 Limitations of study

As far as the limitations of the present study are concerned, they can be mainly focused on the sample size. The sample was small, only 18 pupils of a 4th grade class of primary school, that's why this study took place in the context of a qualitative case study. A small sample size may make it difficult to determine if a particular outcome is a true finding. If more classes participated, therefore more pupils, probably there would be more results because of the larger number of pupils that may create different view of the topic, and the results could be more easily quantified.

Moreover, a different synthesis of class as far as pupils' status or about the part of city may also lead to different results. Eventually, classes without so multicultural synthesis or from other places in Greece may present different results about understanding greenhouse effect, giving another dimension as far as the studied topic is concerned.

5 Conclusions

According to the findings come from this study, the following conclusions can be presented. The conclusions concern the implemented intervention, which has interesting results, the difficulty of topic and how to deal with it in teaching context and the linguistic way of analyze the data, while there are some proposals for future research.

First of all, problem-based intervention in teaching of environmental problems such as greenhouse effect, seems to have an encouraging perspective as far as the understanding of pupils is concerned. The sequence of defining problem, recognizing causes and consequence of problem, suggesting probable solutions and presenting work, can help pupils to form more complete understanding about environmental problems such as

greenhouse effect, leading them more closely to the scientific view.

Secondly, although the difficulty of approaching greenhouse effect, which has been evidenced in other studies, in this study has been shown that it can be overcome by using tools that visualize the problem either if it concerns simulation of greenhouse effect process or if it has to do with drawings by which pupils depict the way they approach this topic, helping them to form better understanding about greenhouse effect.

Finally, focusing to the linguistic expressions as they are depicted in pupils' answers this study shows interesting information about use of scientific concepts about greenhouse effect, accuracy of statements and cognitive understanding of this topic.

For further research, it is suggested to be conducted similar study with pupils of greater age (more than 10 years old) in order to be shown to what extent problem-based approach can help them, since they have greater possibilities of understand both because of age but also because they would be more familiarized with scientific phenomena and scientific reasoning.

Moreover, a comparative analysis between pupils younger than 10 years and pupils elder than ten years could be conducted in order to elicit potential similarities or differences about understanding greenhouse effect, leading to corresponding proposals about teaching such topics in accordance to pupils' age.

Another parameter that can be taken into account is duration that can be longer. Finally, there could be a combination of methods for assessing pupils understanding, using both analysis of pupils' answers in content analysis terms but also analysis of interviews or use of fieldnotes in order to collect more data in a qualitative approach, which is the focus which usually is selected when greenhouse effect is studied in relation to pupils' ideas about this topic.

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