

EDUCATIONAL SOFTWARE ON THE OZONE LAYER DEPLETION

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ABSTRACT

This paper describes the design and the formative evaluation of educational software concerning the ‘Depletion of the Ozone Layer’ designed for the students of the Faculty of Primary Education (pre-service teachers) of the National and Kapodistrian University of Athens. The selection of the topic was based on: i) environmental criteria (importance of the phenomenon, complexity of the phenomenon), ii) societal criteria (local interest, human activities effects), iii) pedagogical criteria (students’ misconceptions about the phenomenon, potential for interdisciplinary teaching, absence of educational material about the phenomenon), and iv) technological criteria (difficulties in performing hands-on experiments for ozone depletion in the laboratory, visualization prospects).

Using the software, students can investigate through simulation experiments and other activities, the following processes: ozone formation, the beneficial role of the stratospheric ozone layer, the ozone depletion process, reactive halogen gases cycle, ozone layer depletion consequences and the formation of the ozone “hole”.

The software was evaluated in the Environmental Science Teaching Laboratory of the Faculty of Primary Education, a compulsory laboratory for the third year students. Three sets of questionnaires were obtained from 127 students: the first was given before the intervention of the software and aimed in identifying students’ ideas about the phenomenon, the second, directly after the students’ use of the software, and the third, one and a half month after in order to examine whether students were able to maintain new knowledge.

Our findings from the analysis of the questionnaires show that some aspects of the phenomenon (UV radiation absorption, substances responsible for the depletion) have been firmly grounded while some of the misconceptions of the students were difficult to change (eg. stratospheric-tropospheric ozone distinction).

KEYWORDS: complex environmental phenomena, ozone layer depletion, computer based learning

INTRODUCTION-GENERAL CONTEXT OF THE STUDY

This study aims to present the development, the implementation and a formative evaluation of educational software concerning the ‘Depletion of the Ozone Layer’ and designed for the students of the Faculty of Primary Education (pre-service teachers) of the National and Kapodistrian University of Athens. The design of this software is intergraded into a general context concerning the teaching of complex environmental issues through the use of Information and Communication Technologies (ICT). Ozone layer depletion was selected as a subject based on the following criteria:

Environmental Criteria: “In 1985, a letter published in *Nature*, had dramatically changed the course of scientific investigations of stratospheric ozone. A team of scientists from the British Antarctic Survey, reported a very large seasonal fall in column ozone values measured over their station at Halley Bay in Antarctica” (Maureen, 2003). Soon after, satellite measurements have shown that in each late winter/spring season, starting in the early 1980s, in a large region centered near South Pole, total ozone was highly depleted. This region has come to be called ozone “hole” and in recent years has reached 25 million square kilometres, which is nearly twice the area of the Antarctic continent (Scientific Assessment, 2002). Despite the fact that at this time ozone depletion is not considered as the most

important environmental issue, it is still one of the major environmental problems of our planet and consequently a crucial subject to be taught in Environmental Science Education.

Societal Criteria: Ozone layer depletion is probably the most characteristic example of how human activities can effect our environment. The uncontrollable use of chlorofluorocarbons during 1930-1974 caused serious problems until 1985, when the first treaty for the protection of the ozone layer was signed in Vienna (Convention for the protection of the ozone layer). According to the United Nations Environmental Programme, the ozone layer is expected to have largely recovered within half a century as a result of the Montreal Protocol and this fact is considered as a remarkable environmental success (UNEP, 2000). On the other hand, what is considered as certain by the scientific community is continually changing, especially in the case of environmental systems which are characterized by high complexity. For example, until recently global warming was not thought to contribute to the ozone layer depletion. New data however, (UNEP, 2006) show that interactions between global warming and ozone layer depletion are complex: ozone changes affects climate and climate affects ozone. We strongly believe, despite the fact that we are living in the greenhouse effect century, that there is a clear need for continuing attention about the phenomenon.

Pedagogical Criteria: Over the last decade numerous researches have revealed that students have difficulties understanding complex environmental phenomena, in which ozone layer depletion holds a prominent position. In particular, students tend to unify the causes and the consequences of global environmental phenomena such as ozone layer depletion and greenhouse effect (Koulaidis and Christidou, 1999). Over 80% of Greek high school students believed that smoke from factories and cars caused damage to the ozone layer, while over 70% thought that radioactivity was also a cause. Also 35% of the students believe that the ozone layer keeps the earth warm and about the same percentage thinks that ozone layer protects us from the acid rain (Boyes, Stanisstreet and Spiliotopoulou-Papantoniou, 1999).

Moreover, in a recent research (Psomiadis, Mandrikas, Tampakis, Tsilidis, Chalkidis, Chalkia and Skordoulis, 2007) we have found that Greek science textbooks of secondary education devote in total only sixteen pages in ten different textbooks (including twelve images) to the depletion of the ozone layer despite the fact that it is considered one of the most important environmental problems of our planet. Besides that, the phenomenon is completely absent from primary education. Interesting is the fact that none of these references to the phenomenon include experimental or any other activity for the students; consequently the phenomenon is presented in a theoretical way. From the above it emerges, that software concerning ozone layer depletion could complement the teaching of the phenomenon in Greek secondary education.

Finally, the teaching of ozone layer depletion can break the boundaries of science courses as it demands an interdisciplinary approach based in physics, chemistry and biology.

Technological & Technical Criteria: Ozone layer depletion is a phenomenon not directly cognizable which is difficult to be simulated inside an educational laboratory. Therefore ozone layer depletion, as atmosphere pollution in general, is a phenomenon suitable to be taught via ICT.

SPECIFIC CONTEXT OF THE STUDY

The design and the implementation of this educational software is an attempt to examine if a short-term intervention could be effective for the teaching of ozone layer depletion in pre-service elementary teachers.

As mentioned above, ozone layer depletion was principally chosen because it offers several levels of complexity, as students will have to deal with a large number of variables. Teaching complex science issues has become an increasingly important challenge for environmental science over the past years. Environmental phenomena such as ozone layer depletion and global warming are very complex issues

(UNESCO, 1980; Gigliotti, 1990; Flogaitis, 1993) requiring critical thinking and knowledge of different science fields (UNESCO 1977; UNESCO 1987) and that's why students and in many cases primary education teachers face great difficulties. Several researches have revealed the fact that students and teachers tend to unify the causes and the consequences of global environmental phenomena.

In recent years the level of scientific understanding of environmental issues expected by both pre-service and in-service teachers has been a matter of a considerable debate. According to Papadimitriou V. (2004), Greek pre-service teachers incorrectly relate climate change with ozone layer depletion and these misconceptions are related to misunderstandings or lack of scientific knowledge involved in the two phenomena.

In a similar with this study research, concerning pre-service teachers, (Groves, 2002) it was found that after a short-term intervention, which was not based in computers, the tendency to conflate causal relationships for global warming and ozone depletion persists. Groves suggests that teachers will have to include political, philosophical and social factors when dealing with complex issues.

The development of effective pedagogical strategies and simulation technologies is considered crucial for teaching complex science issues, both for educational researchers and instructional designers. According to Jonassen (2000), the dialectical nature of technology and the powerful information process provided by the computers in technology aided education, makes ICT-based cognitive tools capable of developing students' critical thinking.

DESIGN AND IMPLEMENTATION

The educational software we present in this study is a hypermedia/multimedia implementation with hierarchical structure. The software was designed to be: usable for our target group (students) taking account of the specific context of the intervention, exact in its function and robustness. We have used text, images, cartoons, different graphical representations and interactive animations. Microsoft PowerPoint was used, not as a presentation maker, but as a hypermedia builder. For this reason «custom shows» techniques were used to build the basic hierarchical structure. Modules from a main menu are called as subroutines, instead of the more common linear presentation structure. Interactive animations, developed in Macromedia Flash in order to achieve small size, are called from those modules (figure 1).

In order to arouse student's interest and link the phenomenon with real life experiences, the software begins with an introduction which is composed of a selection of Greek newspaper cuttings referring to ozone layer depletion or to the ozone "holes".

Apart from the introduction the software is structured on the following thematic units:

- Introductory information (structure of ozone molecule, historical facts, Dobson Units as a measure for ozone concentration)
- Ozone in the atmosphere (Atmosphere's structure, altitude of the ozone layer, distinction between ozone layer depletion and greenhouse effect)
- Ultraviolet (UV) absorption (electromagnetic radiation spectrum, special reference to A,B,C ultraviolet radiation, ultraviolet absorption in relation to wavelength, thickness of the layer and time of the day)
- Ozone layer depletion (the cycle of the chemical reaction of ClO with ozone, the Antarctic ozone "hole", causes and conditions that lead to the formation of the ozone "hole", graphical representations of ozone concentration)
- Consequences and measures of protection (consequences for human health and the environment, CFCs sources, individual measures of protection and international treaties, students as consumers)

The following phenomena were presented through interactive animations:

- Atmosphere's structure, altitude of the ozone layer and UV absorption in relation to wavelength.
- UV absorption in relation to the time of the day.
- The ozone depletion process.

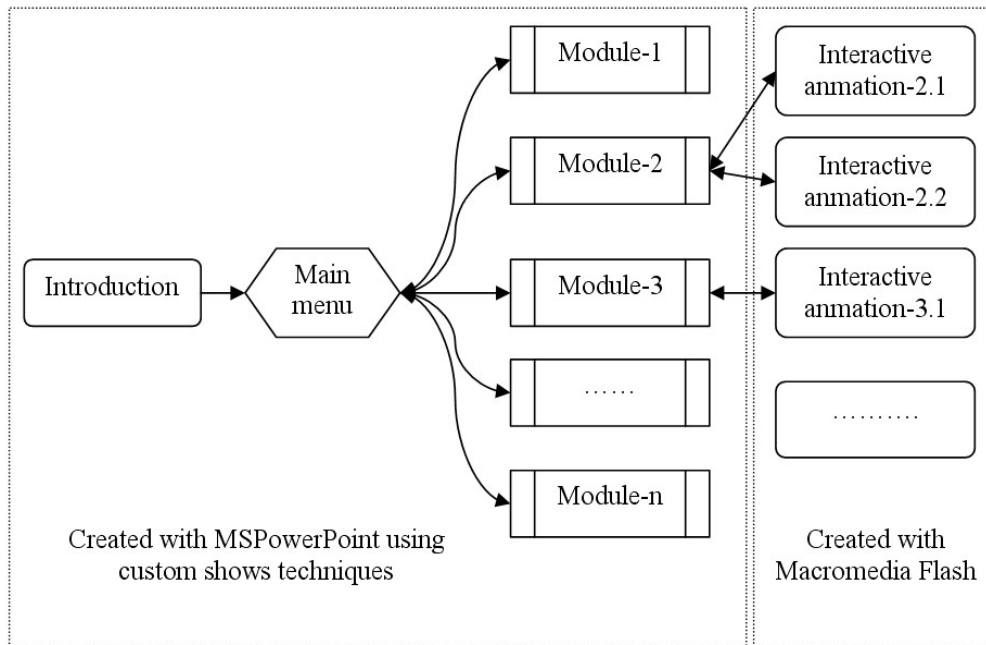


Figure 1. The educational software's structure

Emphasis has been also given to the aesthetic of the software by keeping a uniform style and by following some standard suggested guidelines for using colour at the interface.

In order students to work and make calculations with real data, we included in the software graphical representations with real data, which in some cases were attained only fifteen days before the intervention.

Student's navigation through the software was made with the help of an instrument which include guidelines, questions and specific activities for the students.

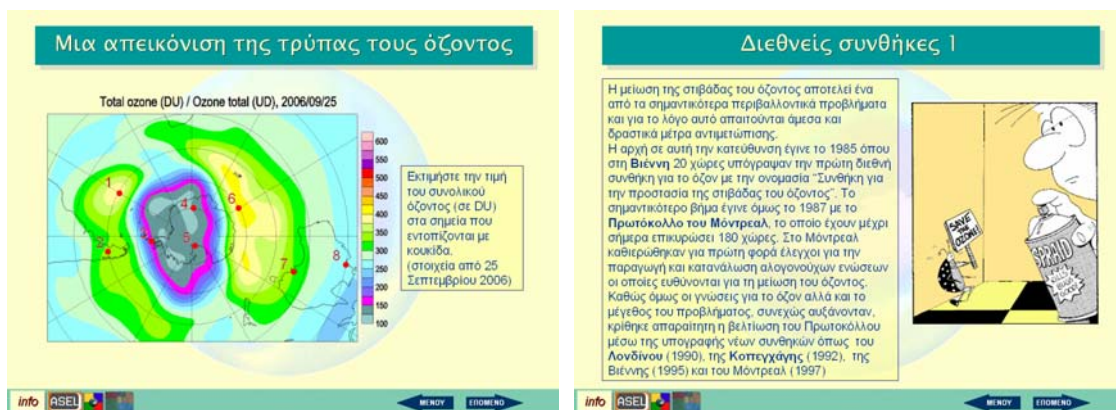


Figure 1. Two screenshots from the software

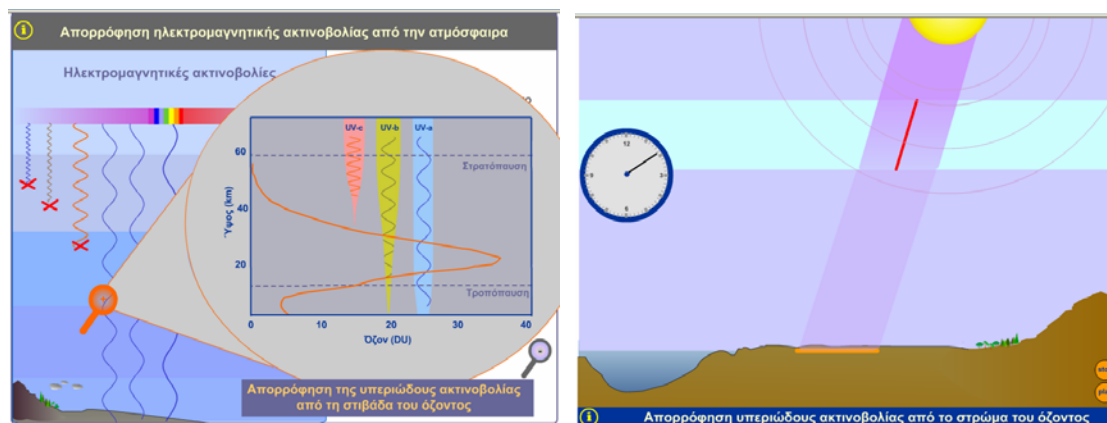


Figure 2. Two screenshots from the interactive animations

FORMATIVE EVALUATION-METHOD

Course

“Teaching of Environmental Science” has been institutionalized as a compulsory lesson in the Faculty of Primary Education (pre-service teachers) of National and Kapodistrian University of Athens since 2003. From 2005, the lesson has been supplemented with a corresponding laboratory. The laboratory of environmental science, in its current form, has duration of seven weeks with each lab taking three hours. One half of the lab is based in hands on experiments while the other half focuses on computer based learning. The students which participated in this research didn’t have any background on environmental science as the theoretical lesson has duration from February to June while the research was accomplished from September to January.

The educational software we present in this study was taught in one of the seven labs (the third) and the intervention had approximately one hour duration.

Instrumentation

Pre-service teacher’s knowledge and attitudes were examined using a pretest and two posttests. The first questionnaire was given before the implementation of the software and aimed in identifying students’ ideas about the phenomenon, the second, directly after students’ use of the software, and the third, one and a half month after in order to examine whether students were able to maintain new knowledge. The two post-tests had exactly the same questions: two open questions and three multiple-choice, while the pre-test had one open question and four multiple-choice. In all multiple-choice questions, students could choose more than one answer.

Population

The population of the research was consisted of 127 pre-service teachers all in the third year of their studies. The second posttest was filled up from 94 teachers only, because it was given at the end of the semester.

Concerning their knowledge, students in Greece come to the Faculty of Primary Education with a poor background in science, as science subjects are not included in university entrance examinations. On the other hand primary’s education university departments require very high scores in the exams.

RESULTS AND DISCUSSION

Pre-test scores:

Question 1: Of what to you believe that ozone molecule is formed?

Only 39 students (30,7%) gave a scientifically accepted answer while 10 (7,9%) answered that ozone is formed by oxygen in general and 46 (36,2%) didn't answer at all. Finally from the 127 students only 21 (16,5%) wrote the chemical type of ozone (O₃).

Question 2: Mark the altitude or the altitudes of the atmosphere that ozone concentration is highly increased.

Table 1. Single answers

0-5 Km	5-15 Km	15-30 Km	30-50 Km	Over 50 Km	NA
3 (2,4%)	17 (13,4)	36 (28,3)	32 (25,2%)	18 (14,2%)	4 (3,1%)

Table 2. Double answers

0-5 Km and 5-15 Km	15-30 Km and 30-50 Km	30-50 Km and over 50	0-5 Km and over 50 Km	0-5 Km and 15-30 Km
5 (3,9%)	5 (3,9%)	2 (1,6%)	4 (3,2%)	1 (0,8%)

Question 3: Which of the following statements do you think is correct? You can choose more than one.

Ozone layer in the atmosphere...

- absorbs the solar biologically harmful radiation.
- prevents the overheating of our planet and the melt of the ices.
- prevents the formation of acid rain.
- protects us from greenhouse effect.
- allows the trap of carcinogenic substances that are emitted from the sun.
- keeps solar rays to prostrate vertical at earth's surface.
- regulates earth's temperature.

Table 3. Question's 3 scores

a	b	c	d	e	f	g
118 (92,9%)	75 (59,1%)	21 (16,5%)	46 (36,2%)	67 (52,8%)	41 (32,3%)	60 (47,2%)

Question 4: 4. Mark the substances and the phenomena which are responsible for the destruction of ozone.

- Radiation
- Greenhouse effect
- Carbon dioxide
- Chlorofluorocarbons
- Tropical forest destruction
- Cars exhaust fumes
- Factories pollutants
- Carbon monoxide
- Climate changes
- Acid rain
- Use of aerosol propellants and refrigerants
- Earth's overheating

Table 4. Question's 4 scores

1	20,5%	7	73,2%
2	13,4%	8	41,7%
3	48,8%	9	11,0%
4	77,2%	10	7,1%
5	26,0%	11	95,3%
6	69,3%	12	11,0%

Question 5: Which of the following phenomena are among ozone layer depletion consequences?
 1. Earth's overheating 2. Greenhouse effect 3. Skin cancer 4. Photochemical smog
 5. Ocular defects 6. Acid rain 7. Tropical forest destruction 8. Lung illness 9. Genetic damages

Table 5. Question's 5 scores

1	2	3	4	5	6	7	8	9
64,6%	37,0%	92,2%	29,9%	48,8%	20,5%	15,8%	31,5%	49,6%

As shown from the pre-test, Greek pre-service teachers have very limited knowledge and serious misconceptions concerning the phenomenon of ozone layer depletion. Regarding the role of ozone layer in the atmosphere (table 3), while almost all students (92,9%) seem to know that ozone layer absorbs the biologically harmful part of the solar radiation spectrum, 59,1% of them believe that ozone layer prevents the overheating of our planet and 47,2% that it regulates earth's temperature.

Students seem to be well informed about the damage that chlorofluorocarbons or the use of aerosol propellants and refrigerants can bring to the ozone layer (table 4) but they also refer in high pretences' cars exhaust fumes (69,3%), carbon dioxide (48,8%) and carbon monoxide (41,7%).

Finally, concerning the possible consequences, (table 5) students refer correctly skin cancer (92,2%), genetic damages (49,6%) and ocular defects (48,8%) but once again they confuse different environmental phenomena as they refer also earth's overheating (64,6%), greenhouse effect (37,0%) and lung illness (31,5 %).

Post-tests scores

Question 1: Of what to you believe that ozone molecule is formed?

First post-test scores: 111 students (87,4%) gave a scientifically accepted answer. The most common misconception was that ozone molecule is formed by three molecules of oxygen (5,5%).

Second post-test scores: 68 students (72,3%) gave a scientifically accepted answer. Once again the most common misconception was that ozone molecule is formed by three molecules of oxygen (17,0%).

Interesting is the fact that after the use of the software more students include in their answers ozone's chemical type: 66 (52%) students in the first post-test and 52 (55,3%) in the second one.

Question 2: Stratospheric ozone...

- a. absorbs all the spectrum of electromagnetic radiation.
- b. absorbs mainly the ultraviolet radiation, X and gamma rays, but not the visual spectrum.
- c. absorbs mainly the ultraviolet radiation.
- d. I don't Know

Table 6. Question's 2 scores

	a	b	c	d
First post-test score (In 127 students)	5 3,9%	16 12,6%	105 82,7%	1 0,8%
Second post-test scores (In 94 students)	1 1,1%	27 28,7%	65 69,2%	1 1,1%

Question 3: Write three possible consequences of ozone layer depletion

Table 7. Question's 3 scores

	Three correct answers	Two correct answers	One correct answers	None correct answer
First post-test (In 127 students)	68 53,5%	33 26,0%	17 13,4%	9 7,1%
Second post-test (In 94 students)	5 5,3%	34 36,2%	34 36,2%	21 22,3%

Question 4: Which of the following substances are responsible for ozone layer depletion?

1. Biocides
2. Carbon dioxide
3. Chlorofluorocarbons
4. Marsh gas
5. Refrigerants
6. Cars exhaust fumes
7. Factories pollutants
8. Carbon monoxide
9. Aerosol propellants

Table 8. Question's 4 scores

	1	2	3	4	5	6	7	8	9
First post-test (In 127 students)	88 69,3%	14 11,0%	117 92,1%	17 13,4%	118 92,9%	30 23,6%	49 38,6%	35 27,6%	123 96,9%
Second post-test (In 94 students)	60 63,8%	30 31,9%	87 92,6%	6 6,4%	74 78,7%	51 54,3%	45 47,9%	13 13,8%	83 88,3%

Question 5: Which of the following statements are correct?

- a. Tropospheric ozone is considered beneficial for human health.
- b. Stratospheric ozone is a pollutant.
- c. Stratospheric ozone absorbs some of the UV radiation.

Table 9. Question's 5 scores

	1	2	3
First post-test (In 127 students)	33 26,0%	4 3,2%	122 96,1%
Second post-test (In 94 students)	41 43,6%	7 7,5%	87 92,6%

As shown in tables 6 and 9 students have achieved very good scores in the two post-tests as regard the wavelengths of the electromagnetic radiation that ozone layer absorbs. In the open question concerning the consequences of ozone layer depletion (table 7) students had very good scores in the first post-test but these score were substantially reduced in the second post-test. Indicative is the fact that in the first post-test only 17 (13,4%) students include in their answers the greenhouse effect or the increase of earth's temperature while in the second the students were 49 (52,1%). Also in the second post-test, students include in their answers new phenomena like acid rain: 9 students (9,6%). Finally as shown in table 8 students include in relatively high scores cars exhaust fumes and factories pollutants.

CONCLUSION

In this paper we described the design, the implementation and the formative evaluation of educational software concerning the 'Depletion of the Ozone Layer'. The main goal of the study was to identify if a short-term intervention based in our software could be effective for the teaching of a complex environmental phenomenon. Despite the fact that in some areas students scores did increased significantly, student's performance was in total moderate. In accordance with other researches dealing with complex environmental issues, our results show that students have great difficulties distinguishing the causes and consequences of different environmental phenomena like ozone layer depletion and greenhouse effect. Finally, we must mention that in order to evaluate the result of the tests, we must take in account the poor scientific background of our students and the fact that due to technical problems the intervention was shorter than we wanted it to be (only one hour) and consequently students didn't had enough time to read the guidelines and run the software with in an pedagogical acceptable time.

Based on the results of the formative evaluation, we will modify our software emphasizing in the distinction of the causes and consequences of different environmental phenomena and simplifying into a more pedagogically appropriate form the graphical representations.

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