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Improving Pre-service Elementary Teachers' Education via a Laboratory Course on Air Pollution: One University's Experience

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Abstract This paper describes the structure of the 'Air Pollution Course', an environmental science laboratory course developed at the Science Education Laboratory of the Faculty of Primary Education, University of Athens, as well as the findings resulting from its implementation by pre-service elementary teachers. The course proposed in this study deals with the problem of air pollution, which has a special local interest in a large and crowded city like Athens, Greece. The design of the 'Air Pollution Course' was based on a combination of experimental study and the use of educational software. All the activities were carried out with the aid of contemporary technological equipment according to the Microcomputer Based Laboratory and to Information and Communication Technologies principles. This approach has encouraging results to the understanding of the problem of air pollution. The laboratory course has improved pre-service elementary teachers' correct use of terms and accuracy in scientific descriptions. These facts suppose deeper conceptual understanding on air pollution phenomena. However, there is a need for further improvement of the pre-service elementary teachers' knowledge in air pollution phenomena, as they still hold misconceptions. The teaching implications of these results are discussed.

Keywords Air pollution · Environmental science education · Pre-service elementary teachers

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Introduction

Proposals recommending the inclusion of an environmental viewpoint in Science Education are becoming more and more common during the last years (Meichtry et al. 2001; Gough 2002; Littledyke 2008). This way, increased time for environmental issues in the curriculum and connection of Science with everyday life are achieved at the same time (Dillon and Scott 2002; European Commission 2007).

Environmental Science is already present as a separate subject in many universities worldwide (see Miller 1996; Scholz et al. 2004; Cunningham and Cunningham 2008). Proposals on the introduction of Environmental Science in primary and secondary education have been presented by many researchers (Edelson 2007) alongside the promotion of education for sustainability (Dillon and Scott 2002; WESTN 2008). This is in line with the call for a 'Decade of Education for Sustainable Development' proposed by UNESCO (2005) and with the 'UNECE Strategy for Education for Sustainable Development' adopted by UNECE (2003).

Environmental Science contributes to the enrichment of teachers' scientific knowledge, as 'it attempts to measure and evaluate the impact of man on the structure and function of social and ecological systems, and which focuses upon the management of these systems for their benefit and survival' (Barrett and Puchy 1977). Also, due to its interdisciplinarity character, Environmental Science aspires to incorporate the social concept of Environmental Education in Science Education rationalisation (see Skordoulis and Sotirakou 2005; Carolan 2006; Carter 2007). Therefore, a considerable effort for the relevant training of pre-service and in-service elementary teachers is expended in many countries (Veal et al. 2002; Bell et al. 2003; Constible et al. 2007).

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The Pedagogical Design of the Course

According to the World Commission on Environment and Development, teachers and their respective training have a significant role to play in the development towards a sustainable society (WCED 1987). Training pre-service elementary teachers in Environmental Science during their academic studies increases the possibility of (a) becoming socially active citizens, environmentally sensitive, scientifically and technologically literate and (b) presenting students with the knowledge and the set of values necessary in order to participate in the protection and improvement of the environment.

In this framework, we have designed, implemented and evaluated a laboratory course on air pollution, in order to increase elementary teachers' understanding of the phenomenon.

The problem of air pollution has local, regional and global dimensions. Smog, photochemical pollution, the greenhouse effect exacerbation, the ozone layer depletion and acid rain are all considered forms of air pollution. Each of these problems has specific consequences on human health, on flora and fauna, on biochemical cycles, on life in ecosystems, on non-living matter and on cultural monuments (Miller 1996; Mason and Hughes 2001; Cunningham and Cunningham 2008). For these reasons, the action taken to control air pollution should be α priority, because it has both short-term and long-term consequences for life on Earth. Moreover, it is important for our study that pre-service elementary teachers develop a special interest for air pollution given that Athens is such a large and crowded city.

The general purpose of the 'Air Pollution Course' for pre-service elementary teachers is a better understanding of air pollution phenomena. Especially, pre-service elementary teachers are expected to (a) recognize the main types of air pollution (b) recognize main air pollutants (c) recognize weather conditions contributing to the concentration of air pollutants over a city (d) substitute their misconceptions about the greenhouse effect and its relation with other forms of air pollution with the scientific ones.

The proposed course includes six activities (Fig. 1), the duration of each being 3 h. Each activity is accompanied by worksheets, which have been created by the authors for this purpose.

A. The 1st activity is introductory and promotes familiarization with sensors and dataloggers. The instructive objectives of this activity for pre-service elementary teachers are (a) to measure specific air pollutants using experimental apparatus and (b) to look for specific data related to local air pollution via Internet.

The pre-service elementary teachers measure the tropospheric ozone level both inside and outside the classroom by

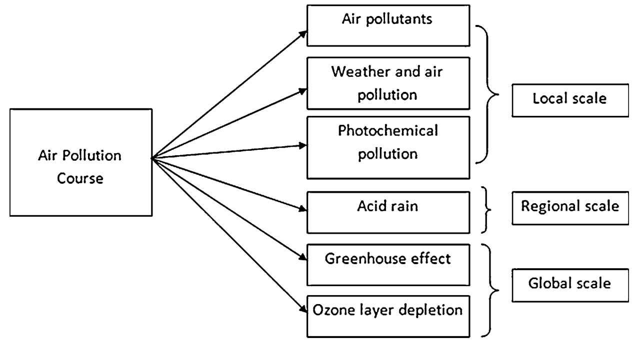

Fig. 1 Items of the 'Air Pollution Course'

using special sticks. Tropospheric ozone is one of the basic components of photochemical smog. They find on the Internet annual and daily diagrams of UV radiation (http://lap.phys.auth.gr/uvindex/uvindex.html or http://lap.physics.auth.gr/uvnet.gr/), in order to connect the stratospheric ozone with ozone layer depletion. Doing this, they can participate in a discussion concerning the differences between tropospheric and stratospheric ozone. Then, they measure the carbon dioxide concentration using a sensor (a) in the laboratory room and (b) over a beaker into which a paper is burned. Carbon dioxide is the main pollutant accused for greenhouse effect exacerbation, an issue which will be developed in the fifth activity of the course.

B. The 2nd activity includes the use of the Internet for collecting data which demonstrate and interpret urban air pollution. The instructive objective for the pre-service teachers is (a) to realize the contribution of weather conditions and topography to air pollution (b) to measure meteorological elements which affect air pollution.

The pre-service elementary teachers look for the daily air pollution report provided by the Greek Ministry of Public Works, Land Planning and Environment (http://www.minenv.gr/), which is derived from a network of 17 monitor stations in the wider area of Athens. They find and study daily, annual and age long diagrams of specific air pollutants through archives provided in the same website. Then, they define each pollutant's sources and discuss human contribution to air pollution. Moreover, they study specialized diagrams which correlate pollutants' concentration in specific areas of the city with air direction and wind speed.

They also measure other meteorological elements using a weather sensor and meteorological instruments. They look for weather forecasts provided by specialized services on the web (http://www.hnms.gr/hnms/greek/index_html or http://www.meteo.gr/), in order to investigate the possibility of any high concentration of air pollutants in Athens that day.

Finally, the pre-service elementary teachers use animations concerning global warming and the carbon cycle provided by US Environmental Protection Agency via Internet (http://www.epa.gov/globalwarming/kids/animations.html), in order to study the consequences of air pollution following our worksheet.

C. The 3rd activity includes the use of software simulations to illustrate the photochemical smog formation. The instructive objective for pre-service elementary teachers is to understand the creation mechanism of photochemical smog, the parameters involved and its consequences on human health.

The pre-service elementary teachers find the application Smog City in the website of Sacramento Metropolitan Air Quality Management District (http://www.smogcity.com/). They can see the image of a functioning city and they have the opportunity to change meteorological parameters, population levels and air pollutants' emissions from specific sources. In this way, they can observe the consequences in tropospheric ozone levels, the general quality of the atmosphere according to the AQI (Air Quality Index Categories) and the times of the day when air pollution is at its peak. Course worksheets constructed by the authors were given to the pre-service elementary teachers. They had to choose specific levels of various elements (temperature, sunlight, cloudiness, wind speed, height of layer inversion), in order to find out which is the most effective parameter in the formation of photochemical smog. Finally, the pre-service elementary teachers were asked to propose solutions or to make decisions on a national, local and personal level for diminishing photochemical pollution.

D. The 4th activity includes the use of educational software which is designed and developed by the authors especially for acid rain study and hands-on experiments. The instructive objective for the pre-service elementary teachers is to understand the creation mechanism of acid rain and its consequences on the environment. The software is especially focused (a) on acid clouds and precipitation formation and (b) on the gradual development of three serious problems created by acid rain, namely forest degradation, aquatic ecosystem destruction and monument corrosion.

The software application consists of a model-landscape for the study of these phenomena and a piloting tool bar. A non urban landscape is pictured within a model-landscape where there is a forest, a lake, a statue and a factory. The pre-service elementary teachers (a) can see changes in air pollutants' emissions during nine successive 'days' (b) can observe the ecosystems' evolution and the gradual catastrophe of the monument and (c) can measure the acidity of air, soil, clouds, lake and rain by the pH scale.

On the piloting tool bar there are some 'functional areas'. The first one is named 'time' and gives the user the chance to 'surf' forward and backward. The others, named 'oxides', 'chemical reactions', 'concepts', 'pollutants', 'maps' and 'biochemical cycles', contain more specific information using simulations of chemical concepts and procedures vital for students' understanding. They also use multiple representations which complete the description of acid rain visualizing its ecological, socio-cultural and technological consequences.

The same results are achieved by hands-on experiments involving acidity measurements of various solutions using pH indicator sticks. Solutions are prepared by the pre-service elementary teachers adding red cabbage indicator, lemon, vinegar, toothpaste or dishwashing detergent into the same quantity of water. Using instructions they are asked to note any differentiation of color and to formulate conclusions about the acidity of each solution based on information from the educational software.

E. The 5th activity includes the use of multiple representation educational software and the implementation of an experimental process for the study of the greenhouse effect. The educational software has been designed and developed by the authors containing information, diagrams, concept maps and simulations so that the pre-service elementary teachers are able (a) to describe the greenhouse effect and to explain its function for the global ecosystem and (b) to list, define and describe the causes and the consequences of the greenhouse effect exacerbation.

In this activity, set in a graphic environment based on seven thematic 'buttons' and directed by our worksheet containing appropriate instructions, pre-service elementary teachers can watch computer simulations, look through diagrams, make emissions' comparisons and study conceptual maps. In this way, they comprehend the formation of the greenhouse effect and the factors that contribute to its exacerbation. They also study the increasing emissions of greenhouse gases due to human actions and calculate their own contribution to the problem using a questionnaire provided by the World Wide Fund for Nature (http://www.wwf.gr). Then, they study the consequences of greenhouse effect exacerbation and Kyoto Protocol's proposals. Finally, the pre-service elementary teachers have to suggest some proposals on an individual, national, regional and global level in order to solve or diminish the problem.

Afterwards, the pre-service elementary teachers measure the carbon dioxide concentration and the temperature by a sensor in the interior of a closed beaker in three successive phases: without light, with light and after channeling carbon dioxide produced by the reaction of soda and vinegar. In this way, they have a chance to discuss the analogies of the experiment in relation to the greenhouse effect and its exacerbation.

F. The 6th activity pertains to ozone layer depletion and to the creation of the 'ozone hole' and is presented by the use of the educational software created by the authors. This software is a presentation containing basic and in-depth information about stratospheric ozone, images, diagrams and animations. The software focuses on the following thematic units: (a) Introductory information (structure of ozone molecule, historical facts, Dobson Units as a measure for ozone concentration), (b) Ozone in the atmosphere (atmosphere's structure, ozone concentration in connection with altitude, the distinction between stratospheric and troposheric ozone), (c) Ozone layer depletion (the chemical reaction of ClO with the ozone, the Antarctic 'ozone hole', causes that lead to the formation of the 'ozone hole', graphical representations of ozone concentration) and (d) Consequences and measures of protection (consequences on human health and the environment, CFCs sources, individual measures of protection and international treaties). The pre-service elementary teachers follow the presentation at their own pace of learning and they have to answer appropriate questions provided by our worksheet.

All the activities that are described above are carried out with the aid of contemporary technological equipment: PCs, sensors and dataloggers, according to the Microcomputer Based Laboratory (MBL) and to Information and Communication Technologies (ICT's) principles.

On one hand, the MBL is a laboratory practice based on a PC connected through special software with a small selection of sensors. The course utilizes MBL in teaching air pollution, because it places emphasis on the development of several skills, such as observation, formulation of forecasts and ability of justification (Browne and Laws 2003; Laws 2004). MBL fosters the ability of reading graphic representations (Mokros and Tinker 1987; Ainley et al. 2000), like diagrams of pollutants, histograms of temperature, relative humidity, wind speed and direction, scales of acidity, chromatic Dobson Units scales, bar diagrams of emissions etc.

On the other hand, Information and Communication Technologies (ICT's) play an important, supporting role in Environmental Science Education, since the effectiveness of models, representations and simulations in the investigation and comprehension of complicated natural and industrial functions has been proved (Mellar et al. 1994; Linn 1999; Cox 2000). We use ICT in teaching air pollution, because the relative phenomena are not often perceptible by human senses or occur in the upper atmosphere. They also present an increased complexity and this is why it is difficult to be represented in the laboratory.

The 'Air Pollution Course' activities are implemented according to inquiry-based learning method, in a collaborative learning environment (Edelson et al. 1999; Minstrell and Van Zee 2000). This method is the most suitable when the main target is to help pre-service elementary teachers to study, describe and comprehend functions and procedures that underlie and constitute complicated systems. Moreover, the pre-service elementary teachers are involved in collaborative learning procedures that encourage the development of social abilities and contribute to the development of critical thinking (see Matsagouras 1998; Brown 2000; Plevyak 2007).

Research Questions

The 'Air Pollution Course' was designed to teach pre-service elementary teachers during their undergraduate studies. This research has been designed and implemented in order to investigate the impact of the course on pre-service elementary teachers' understanding regarding the following questions:

- To what extent are pre-service elementary teachers able to name the major forms of atmospheric pollution?
- To what extent are pre-service elementary teachers able to name specific atmospheric pollutants?
- To what extent do pre-service elementary teachers realize the impact of weather on air pollutant concentrations over big cities?
- Are pre-service elementary teachers able to give a definition of the 'ozone hole'?
- To what extent are pre-service elementary teachers aware of the greenhouse effect and its relationship with forms of atmospheric pollution?

The above research questions were selected because (a) they refer to the local, regional and global scale of the problem of air pollution, (b) recently an AQI (Air Quality Index) has been adopted by European authorities (http://www.airqualitynow.eu/about_indices_definition.php) and c) air pollution is of great local interest, as seen by daily records of air pollutants in the wider area of Athens (provided at http://www.minenv.gr/1/12/122/12204/g1220400.html). Therefore, citizens and especially prospective teachers have to be aware of air pollution forms, elements, causes and solutions.

Sample: Method

Participants were 78 pre-service elementary teachers (6 males and 72 females, all aged 21 years old) in their 3rd year of studies attending the laboratory lesson 'Environmental Science Education' in the University of Athens, Faculty of Primary Education during winter semester of 2008–2009. They were divided into five classes, which attended the 'Air Pollution Course' on a different day during six consecutive weeks. Concerning their knowledge background, students of tertiary education in Greece have a rather poor knowledge level in environmental science, as this subject is not included in the university entrance examinations and appears limitedly in the secondary education curriculum. The use of the term 'students' from here to the rest of this paper implies this sample of pre-service elementary teachers.

For the purpose of the research a questionnaire consisting of five questions corresponding to the afore-mentioned questions was designed. Four questions were open-ended and only one question was closed. The pre-service elementary teachers answered these questions before the first lesson and again about 30 days after the last lesson of the 'Air Pollution Course'. The completed questionnaires were encoded. Pre- and post-tests results were compared.

The questionnaire was based on similar instruments of previous research based on open-ended questions (Thornber et al. 1999; Andersson and Wallin 2000; Papadimitriou 2004) or agreement with statements (Dove 1996; Groves and Pugh 1999; Khalid 2003). In order to gain insight into participants' knowledge, we have chosen more open-ended questions, which actually were:

1. Name the different types of atmospheric pollution that you know.
2. Name the three most important air pollutants.
3. Do you think that weather conditions affect air pollution? Please explain.
4. What is the 'ozone hole' in your opinion?

The last question consisted of 6 statements regarding the greenhouse effect and relevant misconceptions recorded in the literature (Dove 1996; Boyes and Stanisstreet 1998; Koulaidis and Christidou 1999; Groves and Pugh 1999; Andersson and Wallin 2000; Khalid 2003; Papadimitriou 2004). Pre-service elementary teachers were asked to judge whether the statements were true or false:

1. Greenhouse effect is a physical process which maintains the average temperature of our planet in a level appropriate for life support.
2. The 'ozone hole' is responsible for the exacerbation of the greenhouse effect.
3. Carbon dioxide is mainly charged with the greenhouse effect exacerbation.
4. Chlorofluorocarbons are mainly blamed for the greenhouse effect exacerbation.
5. The greenhouse effect exacerbation is possible to lead in long-term climate changes.
6. Acid rain is a consequence of the greenhouse effect exacerbation.

The initial form of the questionnaire containing more types of questions was piloted with 30 teacher students, pre-service elementary teachers in Faculty of Primary Education, University of Athens, Greece. Feedback from participants was good and the estimated Cronbach's alpha revealed a high degree of reliability for the test scores (a = 0.98). After some corrections the questionnaire was checked by three faculty members one from the field of environmental science and two from the field of science education in order to check the construct validity of the instrument. Neither the participants from the pilot study nor their scores were included to the final analysis.

Data Analysis

Students' answers to open-ended questions were assessed by two of the authors in order to establish high reliability. The degree of their agreement was very high (98.7 %) meaning they disagreed in only one answer. This answer was then discussed by the two experts and they resulted in an agreement.

Students' answers in the first and the second question were assessed as right or wrong and correct were considered those answers that mentioned: smog, photochemical smog, acid rain, stratospheric ozone depletion and greenhouse effect. Therefore, if someone answered all the above had the most correct answers. As incorrect were considered the answers that mentioned: pollutants of factories, waste, sprays, smoke, exhaust gases and similar general terms.

Concerning the third and the fourth question pre-service elementary teachers' answers were characterized as: absolutely right, partially right, wrong, don't know. As right was considered any answer mentioning sunshine and stillness as factors increasing air pollution and strong wind decreasing air pollution. A right answer referring to 'ozone hole' should mention CFCs as the substances that destroy the ozone layer and a reference to the poles as the Earth's location where this layer has been strongly damaged.

Concerning the fifth question each answer was characterized as right or wrong by the criterion of scientific acceptability.

Data were analyzed by the authors making use of the statistical program SPSS v.16.1 and differences in students' answers before and after the course were tested by the use of Chi-square test and Wilcoxon Signed-Ranks Test as the distribution of the data was not normal (Kolmogorov–Smirnov test, $p > .05$).

Results

Students' answers regarding the types of atmospheric pollution were significantly improved after the implementation of the course ($\chi^2 = -5{,}988$, $p < .001$). Before the course only 18 % of the participants could mention at least

Table 1 Distribution of the number of types of atmospheric pollution stated by each student before and after the implementation of the course

Number of types of air pollution	Before the course n (%)	After the course n (%)
5	0 (0)	2 (3)
4	0 (0)	9 (11)
3	14 (18)	27 (35)
2	21 (27)	29 (37)
1	8 (10)	3 (4)
0	35 (45)	8 (10)
Total	78 (100)	78 (100)

Table 2 Distribution of students' answers concerning air pollution forms

Forms of air pollution	Before the course n (%)	After the course n (%)
Greenhouse effect	33 (42)	48 (61)
Ozone hole	29 (37)	53 (68)
Acid rain	28 (36)	53 (68)
Exhaust gases	19 (24)	7 (9)
Cloud of smoke	16 (20)	0 (0)
Noise/sound pollution	4 (5)	0 (0)
Forest fires	1 (1)	0 (0)
Microparticles	1 (1)	0 (0)
Photochemical smog	0 (0)	25 (32)
Smog	0 (0)	4 (5)

three types of air pollution whereas after the course 49 % of students could (Table 1).

Before the course, the pre-service elementary teachers in our research reported as forms of air pollution the greenhouse effect (42 %), the ozone hole (37 %) and the acid rain (36 %). General terms, such as 'exhaust gases' and 'cloud of smoke' were reported in lower percentages (24 and 20 % respectively), without further clarifications about their content. After the course, an obvious increase of the correct answers was noted and an improvement in the accuracy of the terms was observed: the greenhouse effect was reported by the 61 % of the sample, the 'ozone hole' and the acid rain by 68 %, whereas the general term 'exhaust gas' was diminished to 9 %, the general term 'cloud of smoke' disappeared, and new, more precise terms were reported, such as 'photochemical smog' (32 %) and 'smog' (5 %) (Table 2).

Answers about important air pollutants also improved in a statistical significant manner ($\chi^2 = 41.7$, $df = 3$, $p < .001$) after the course. Before the course only 20 % of the sample could mention 3 air pollutants. After the course this percentage more than tripled since it increased up to 70 %. In addition, pre-service elementary teachers that could not state any air pollutant decreased from 30 to 5 % (Table 3).

Table 3 Number of air pollutants reported before and after the implementation of the course

Number of air pollutants reported	Before the course n (%)	After the course n (%)
3	16 (20)	55 (70)
2	19 (24)	9 (12)
1	20 (26)	10 (13)
0	23 (30)	4 (5)
Total	78 (100)	78 (100)

Table 4 Distribution of the reported air pollutants before and after the course

Air pollutant	Before the course n (%)	After the course n (%)
Carbon dioxide	47 (60)	54 (69)
Carbon monoxide	24 (31)	24 (31)
Exhaust gases	20 (26)	15 (19)
CFCs (chlorofluorocarbons)	14 (18)	45 (58)
Sulfur dioxide	8 (10)	24 (31)
Nitrogen oxides	7 (9)	6 (8)
Ozone	5 (6)	6 (8)
Nitrogen monoxide	6 (8)	27 (35)
Sprays	4 (5)	2 (3)
Freon	3 (4)	0 (0)
Sulfur combinations—sulfur oxides	3 (4)	12 (15)
Chemical waste	3 (4)	0 (0)
'Cloud of smoke'	2 (3)	0 (0)
Oxides	2 (3)	0 (0)
Nitrogen dioxide	1 (1)	4 (5)
Methane	0 (0)	7 (9)

From the results in Table 4 we can see that before the course carbon dioxide was the most known air pollutant (60 %), followed by carbon monoxide (31 %), CFCs/chlorofluorocarbons (18 %) and sulfur dioxide (10 %). The use of general terms, such as 'exhaust gases' (26 %), 'sprays' (5 %), 'chemical waste' (4 %), 'cloud of smoke' (3 %) and 'oxides' (3 %), clearly signifies a lack of specialized knowledge about air pollutants and their sources. After the 'Air Pollution Course' students that reported carbon dioxide as a significant air pollutant increased from 60 to 69 %. There was also an impressive increase in the statements of CFCs (57 %), carbon monoxide (31 %) and sulfur dioxide (31 %). On the other hand fewer students named general terms as air pollutants and more air pollutants were named by their exact name, as nitrogen monoxide (35 %), methane (9 %), ozone (8 %) and nitrogen dioxide (5 %) (Table 4).

Table 5 Distribution of students' conceptions—before and after the course—about whether the weather conditions affect air pollution

Type of answer	Before the course n (%)	After the course n (%)
Right	0 (0)	19 (24)
Partially right	30 (38)	46 (59)
Wrong	23 (30)	5 (6)
Don't know	25 (32)	8 (10)
Total	78 (100)	78 (100)

Table 6 Distribution of students' conceptions—before and after the course—about the 'ozone hole'

Type of answer	Before the course n (%)	After the course n (%)
Right	0 (0)	34 (44)
Partially right	41 (53)	41 (53)
Wrong	27 (35)	3 (4)
Don't know	10 (13)	0 (0)
Total	78 (100)	78 (100)

Concerning whether weather conditions affect air pollution we also observed an improvement in pre-service elementary teachers' answers. Before the course none of the participants gave a completely right answer. After the course this percentage increased up to 24 %. In addition, the part of the sample which gave a partially right answer increased from 38 to 59 %. Finally, wrong answers reduced from 30 to 6 % and pre-service elementary teachers that were unable to give an answer reduced from 32 to 10 % (Table 5) and these differences are statistically significant ones ($\chi^2 = 42{,}7$, $df = 3$, $p < .001$).

Comparing the content of these answers a thorough improvement has been recorded. Before the course 27 % of the pre-service elementary teachers expressed the aspect that strong winds blow away smog in contrast with stillness which increases air pollution and 21 % recognized that weather conditions affect air pollution in that sunshine, high temperatures and relative humidity reinforce air pollution and create smog. After participating in the 'Air Pollution Course' the total of the sample recognized that weather conditions affect air pollution formation. In addition, they could provide a better argumentation, as illustrated below:

> 'sunshine, high temperatures and relative humidity increase air pollution and create smog' (59 %), 'strong wind blow away smog and stillness increase air pollution' (53 %),
> 'sunshine and rain create secondary pollutants' (11 %), 'pollutants are relocated far away from emission areas' (5 %), 'temperature inversion conditions are created' (4 %), 'contribute to acid rain creation' (4 %), 'photochemical pollution is created' (3 %), 'tropospheric ozone is created' (3 %).

Concerning the ozone hole, we also recorded an improvement on pre-service elementary teachers' knowledge. Before the course none of the participants gave an absolutely right answer. After the course this percentage increased up to 44 %. In addition, the part of the sample which gave a wrong answer lowered from 35 to 4 %, the 'don't know' answers disappeared (Table 6) and these differences are statistically significant ones ($\chi^2 = 63.2$, $df = 3$, $p < .001$).

Comparing the content of these answers a great improvement has been recorded. Before the implementation of the course, almost only 1 % of the pre-service elementary teachers made reference to the poles in their answers. A few pre-service elementary teachers (10 %) referred to substances which destroy the stratospheric ozone layer and only 6 % made a distinction between stratospheric and tropospheric ozone. Also, 32 % of the sample before participating in the 'Air Pollution Course' described the ozone layer depletion using words like 'empty space', 'blank space' and 'hole'. Two of the most characteristic examples are given below: *'Ozone hole is probably a break in the ozone layer whence the harmful radiation passes through' 'Ozone hole is an empty space in the ozone layer which has been created by different causes…'*.On completion of the course, 35 % of the answers made a reference to the poles and 23 % made a reference to the substances that destroy the ozone layer. The most impressive result is the increased proportion of the pre-service elementary teachers, who made a distinction between tropospheric and stratospheric ozone (from 6 % up to 45 %).

Finally, examining students' answers to the six statements of the questionnaire, there were statistically significant differences only for the first two statements (Table 7). Characterizing as *zero* the wrong answer and *one* the right answer, in both statements students scored better after the course, but in the second statement the majority of students still maintains incorrect aspects about the ozone hole and its contribution to the exacerbation of the greenhouse effect:

- The greenhouse effect is a physical process which maintains the average temperature of our planet in a level appropriate for life support. ($z = -6.9$, $p < .001$, $Mdn_{pre} = 0.0$ $Mdn_{post} = 1.0$, $Mean_{pre} = 0.27$, $Mean_{post} = 0.91$).
- The 'ozone hole' is responsible for the exacerbation of the greenhouse effect. ($z = -2.8$, $p < .001$) $Mdn_{pre} = 0.0$ $Mdn_{post} = 0.0$ $Mean_{pre} = 0.22$, $Mean_{post} = 0.42$).

Table 7 Distribution of correct answers to specific statements before and after the course

Statements	Before the course n (%)	After the course n (%)
Greenhouse effect is a physical process which maintains average temperature of our planet in level appropriate for life support. (True)	21 (27)	71 (91)
The "ozonehole" is responsible for the exacerbation of the greenhouse effect. (False)	17 (22)	33 (42)
Carbon dioxide is mainly charged with the greenhouse effect exacerbation. (True)	48 (61)	50 (64)
The Chlorofluorocarbons are mainly blamed for the greenhouse effect exacerbation. (False)	42 (54)	37 (47)
The greenhouse effect exacerbation is possible to lead in long-term climate changes. (True)	74 (95)	77 (99)
Acid rain is a consequence of the greenhouse effect exacerbation. (False)	43 (55)	53 (68)

It seems that confusion between carbon dioxide and CFCs continues to exist as right answers about the role of CFCs remained low before and after the course as about half of the students hold misconceptions ($Mean_{pre} = 0.54$, $Mean_{post} = 0.47$). Students also connected incorrectly the acid rain with the greenhouse effect exacerbation. ($Mean_{pre} = 0.55$, $Mean_{post} = 0.68$). Students' conceptions about the role of carbon dioxide in the exacerbation of the greenhouse effect remained the same before and after the course as only about 64 % of the students hold the right conceptions ($Mean_{pre} = 0.62$, $Mean_{post} = 0.64$). The statement that gathered the most right answers was the 5th: the majority of students ($Mean_{pre} = 0.95$, $Mean_{post} = 0.99$), knew that the greenhouse effect exacerbation is possible to lead in long-term climate changes.

Discussion

From our results emerge two significant aspects. On one hand, they are encouraging for pre-service elementary teachers' education, as they record a general improvement on their answers on air pollution phenomena. On the other hand, percentages of right answers in some cases remain low, thus revealing the existence of misconceptions or lack of true understanding. The data analysis summarized above shows that the laboratory course has improved pre-service elementary teachers' correct use of terms and accuracy in scientific descriptions. These facts suppose deeper conceptual understanding on air pollution phenomena. After the implementation of the 'Air Pollution Course' our sample could refer to concrete forms of air pollution and were able to name specific pollutants. They were convinced that meteorological phenomena affect air pollution and they improved their understanding of how this interaction takes place. In relation to the ozone layer depletion, a high rate of correctness and accuracy in the use of terms describing the concrete phenomenon has been recorded. Nevertheless, results show that there is still space for improvement in pre-service elementary teachers' knowledge.

These findings are consistent with relevant research on pre-service teachers. A research on environmental literacy of 214 teacher education students in Israel revealed that 'while their environmental attitudes were positive, both as beginning and advanced students, their level of environmental knowledge remained low' (Yavetz et al. 2009). Another research about primary teachers' explanations of physical phenomena in Greece confirmed that 'primary teachers did not have a secure understanding of the physical phenomena and appeared to hold misconceptions similar to those that would be expected of their pupils. It seems reasonable to suppose that their thinking dates back to when they, themselves, were pupils. Furthermore, their experience of teaching these topics does not seem to have engendered any significant conceptual changes' (Papageorgiou et al. 2010).

Pre-service elementary teachers that took part in our research seem to confuse causes and consequences of air pollution, a finding consistent with relevant ones from the literature (Dove 1996; Boyes and Stanisstreet 1998; Groves and Pugh 1999; Khalid 2003; Papadimitriou 2004). General terms like 'gases', 'fumes' and 'smoke' are very often stated in previous research (Thornber et al. 1999; Myers et al. 1999).

None of the Greek pre-service teachers that took part in our research gave a right answer concerning the 'ozone hole'. This result is consistent with previous research, which supports the assumption that Greek high school students think (50 % of the boys and 39 % of the girls), that ozone layer depletion produces the greenhouse effect (Boyes et al. 1999). The same findings (56 % false answers) are verified for pre-service high school science teachers in another research, which indicates that the phrase 'hole in the ozone' may be a cause of some confusion among the students (Khalid 2003). There is a variety of misconceptions on this issue, maybe because it is quite difficult to define as it is invisible and occurs in the upper atmosphere (Boyes et al. 1999; Andersson and Wallin 2000; Cordero 2001; Khalid 2003; Leighton and Bisanz 2003; Papadimitriou 2004; Pekel and Ozay 2005). In addition, confusion between carbon dioxide and CFCs exists even after the completion of the course as only about half of the students gave right answers about the role of CFCs before and after the course. Students also connected incorrectly the acid rain with the greenhouse effect exacerbation. This result is also consistent with previous research, which notes that there is a tendency to combine one issue with the other (Khalid 2003). In general, acid rain is mentioned as an individual environmental problem by the minority of the secondary students (Myers et al. 1999; Thornber et al. 1999).

A possible cause of low environmental knowledge is the existence of misconceptions in school textbooks, so 'with a high level of misconception in earth science understanding of trainee teachers, practicing teachers, and textbook writers, there is a major task ahead to improve the education of all these groups' (King 2010). The role of textbooks is underlined by another research about the hydrological cycle: 'Our textbooks and activities are reinforcing a particular conception of the form and relevance of the hydrologic cycle to the students' environment that does not prepare students to apply a sophisticated understanding of the hydrologic cycle in their interactions with the environment and environmental management as children or adults' (Shepardson et al. 2009). Nevertheless, some researchers attribute findings of students' poor knowledge and hold of misconceptions to the research method: 'what is reported in the literature and these difficulties should be attended to in the teaching and learning process. The wider question that is raised through our results is what is a pedagogically meaningful way of studying knowing about such complex issues' (Jakobsson et al. 2009).

This discussion has obtained more dimensions in recent years, given that inquiry-based learning incorporates wider didactical and also epistemological aspects. Thus, some researchers conclude that 'concerns and difficulties of enacting practical work are not only the issues of background knowledge, materials, or time but also the questions of a complex schema of experiences, values, and traditions of knowledge and teaching in our society' (Kim and Tan 2011). By 'Air Pollution Course' we ordered some practical work in the form of hands-on activities, so as pre-service elementary teachers foster their skill of measurement, observation, making hypothesis and predictions. Our activities were not 'cookbook- based' but also could not be characterized as an open inquiry. They were based on the use of archived online data, just like in other scientific concepts: 'Utilizing Web-based archived data sources appears to be a promising instructional strategy for the development of a scientific understanding of tides among preservice teachers' (Ucar et al. 2011). They were also based on the use of simulations, which have been proved effective in teaching various scientific phenomena (see Lefkos et al. 2011; Scalise et al. 2011).

Teaching Implications

'Air Pollution Course' was an innovative course that combined both experimental study and the use of educational software. Nevertheless, the correct use of terms recorded in most activities does not signal safely conceptual understanding of air pollution phenomena. In order to achieve this, it is recommended that further research should be designed and implemented. For this purpose, more time should be allocated for training, student-centered methodologies should be adopted, specific presentations should be prepared, and a distinction among global environmental atmospheric problems, causes and consequences should be emphasised.

We think that long term measurements and record of various parameters related to local air quality could offer a deeper understanding of air pollution phenomena (see for example Thomas 2010). A wider use of hands-on activities in relation with the existing software simulations would be more effective. Additional time for teaching each environmental problem could offer to pre-service elementary teachers more chances to study in depth and separately each phenomenon. At the end of the course, an additional refresher lecture would be useful to elaborate participants' views, aspects, conceptions and misconceptions.

Appendix: Questionnaire About Air Pollution

1. Name the different types of atmospheric pollution that you know.

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2. Name the three most important air pollutants.

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3. Do you think that weather conditions affect air pollution? Please explain.

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4. What is the 'ozone hole' in your opinion?

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5. Can you judge whether the statements are true or false:

Statements	True or false
Greenhouse effect is a physical process which maintains the average temperature of our planet in a level appropriate for life support	
The 'ozone hole' is responsible for the exacerbation of the greenhouse effect	
Carbon dioxide is mainly charged with the greenhouse effect exacerbation	
Chlorofluorocarbons are mainly blamed for the greenhouse effect exacerbation	
The greenhouse effect exacerbation is possible to lead in long-term climate changes	
Acid rain is a consequence of the greenhouse effect exacerbation	

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