Teaching Air Mass Movements to Pre-service Elementary Teachers

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Abstract. *In the present paper a teaching sequence on horizontal and vertical air mass movement is described, which uses hands-on experiments and software simulations and it is aimed at pre-service elementary teachers.*

More specifically, the teaching sequence aims at the wind formation understanding based on air pressure differences, at the weather front formation and the temperature inversion formation understanding based on fluid circulation.

The proposed teaching sequence was practised on pre-service elementary teachers, specifically undergraduate students of the Faculty of Primary Education of the University of Athens, during the winter semester of 2008-09. Research findings appear to be encouraging.

Keywords. Environmental Science, Meteorology, Pre-service Elementary Teachers.

1. Introduction

More and more, requests are being made for teachers to be instructed in Physical Sciences during their initial training [10] [7]. Similar propositions are made by various researchers [25] [22]. In addition, proposals for the introduction of environmental dimension in Physical Science Teaching are also formulated [13] [11]. Environmental Science, as a multidisciplinary subject, aspires to incorporate the Physical Sciences rationalism with the social sensibility and values of Environmental Education [19]. A great effort for training pre-service and in-service elementary teachers in Environmental Science has been made all over the world [3] [4] [23] [2] [5].

Meteorological phenomena, as a part of the Environmental Science, are been didactically approached either by software [15] [26] or by hands-on activities [16] [8]. Additionally, research on students' conceptions about weather [21] [1] [6] [20] [17] [9] [18] has revealed that students of any age find difficult to explain how the wind is created and make use of misconceptions to explain its formation.

Based on research findings and recommendations, we have developed a teaching sequence aimed at pre-service elementary teachers in order to teach meteorological phenomena and especially air mass movements. In this work, we present this teaching sequence and its results on pre-service elementary teachers currently training in the Faculty of Primary Education of the University of Athens.

2. Research aims

The teaching sequence aimed at providing basic knowledge about three important scientific concepts. The first was wind, defined as the horizontal movement of air masses, which is generated by air pressure differences between two locations on the ground. The second was the weather fronts and that they come into being when air masses of different temperature, speed and density run into each other during their horizontal movement. The third and final was temperature inversion formation that is mostly created due to the freezing of the ground and the

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subsequent freezing of the air near the ground during the night. As a result, the temperature decrease with altitude is altered, vertical air mass movement is blocked and a warm air layer is trapped between two colder layers increasing air pollutants' concentration near the ground. Our research questions are:
a) to what extent pre-service elementary teachers were aware of air mass movements before teaching
b) to what extent the proposed teaching sequence improved their knowledge

3. The teaching sequence

The teaching sequence is based on three hands-on experiments and on two software applications provided via Internet.

The first experiment simulates the creation form of the wind, which is the horizontal air mass movement near the ground [12]. It is implemented by the Density Flow Model apparatus (Sargent-Welsch WL1359J-01) and contributes to wind formation understanding based on air pressure differences. As an additional instructional tool, a software application provided at http://www.phys.ufl.edu/~matchev/MET1010/notes/ ActiveFigures/A_54_files/A_54.swf is used.

The second experiment simulates the horizontal movements of air masses with different temperature and the subsequent weather front formation. It is also implemented by the Density Flow Model apparatus (Sargent-Welsch WL1359J-01) and is accompanied by appropriate slides on the computer screen.

The third experiment is implemented by the Air Mass Generator apparatus (Sargent-Welsch WL6837E) and simulates the vertical air mass movements, which increase or reduce air pollution in relation with temperature differences among air layers. This experiment aims at teaching the temperature inversion formation, in the case that the vertical air mass movement is blocked because of the low temperature of the air near the ground. The experiment is accompanied by a software application provided at http://www.airinfonow.com /html/activities.html.

The didactical methodology used is based in the guided inquiry model [14]. Following the inquiry-based learning students are exerted to make observations, to pose questions, to test hypotheses, to make predictions, to do experiments and to conduct conclusions. Pre-service elementary teachers followed a series of hands-on and written activities, using and recording their results in an appropriate instructional sheet.

4. Research methodology

The teaching sequence was practised on 60 undergraduate students of the Faculty of Primary Education of the University of Athens, during the winter semester of 2008-09, as part of an elective course named "Physical Sciences & Environment – A laboratory approach".

Data came from a) questionnaires submitted a week before and a week after the instruction b) instructional sheets completed during the activities c) recorded discussions among pre-service elementary teachers during the instruction d) recorded interviews given after instruction. Data was processed with the semantic content analysis method [23].

5. Results and discussion

Results show that pre-service elementary teachers, prior to the instruction, possessed a poor command of wind creation mechanisms, of wind naming, direction and velocity assessment and of orientation pattern. They also had no concepts related to weather fronts and temperature inversion. The great majority declared that they had learnt nothing about wind during their prior education. Our teaching sequence seems to have addressed this lack of knowledge.

Table 1. Total answers about wind formation

How is atmospheric wind created?	Before teaching		After teaching	
	Num. of p.t. n=60	Percentage	Num. of p.t. n=60	Percentage
I don't know	39	65%	8	13%
Various erroneous answers	10	16%	5	8%
Through temperature differentials	7	12%	13	22%
Through airstreams	2	3%	5	8%
Through barometric systems	1	2%	7	12%
By air pressure differences	1	2%	22	37%

The same question "How is atmospheric wind created?" has been included in both pre-test and post-test. In the pre-test, 65% of the pre-service elementary teachers answered "I don't know" and only one mentioned air pressure differences as a cause (Table 1). In the post-test, 37% gave the correct answer: "Wind is created by air pressure differences between two areas" (PET22). Furthermore, most of them appoint the precise direction of the movement and discriminate between vertical and horizontal movements. In addition, only 13% declared "I don't know" and "various erroneous answers" reduced from 16% to 8%.

However, there is room for improvement, given that many answers reveal confusion on concepts and various misconceptions. 22% of the pre-service elementary teachers continued to consider temperature differences as the cause of the wind. They confuse surface horizontal air movements, which actually constitute wind, with vertical air movements, which are caused by temperature differences and come before horizontal movements. "The wind is created when warm air masses lay upwards and cold air masses lay downwards creating airstreams" (PET24). Obviously, this answer contains scientifically correct elements, though their correlation cannot explain wind formation in an acceptable way.

It is thus our estimation that there are three kinds of conclusions to be made. At first, some of the pre-service elementary teachers speak with macroscopic terms and usually describe only the observable result of the experiment, because they cannot give a full explanation based on appropriate scientific concepts concerning fluid circulation. Other pre-service elementary teachers fail to discriminate between vertical and horizontal movements, because they cannot discriminate between temperature differences and air pressure differences. Finally, there is confusion between cause and effect, since some of the pre-service elementary teachers believe that the existence of high barometric pressure causes air down-draught movement, while in reality the air down-draught movement creates high barometric pressure on the surface.

Concerning front formation, the pre-test shows that 43% of the pre-service elementary teachers ignored the phenomenon and that only 22% selected the right answer in a closed form question (Table 2). During the interviews this general impression was confirmed.

Table 2. Answers about weather fronts' formation before teaching

When a warm air mass arises over a cold air mass, we observe:	Num. of p.t. n=60	Percentage
A. A cold weather front	12	20%
B. A warm weather front	13	22%
C. Sea breeze	9	15%
D. I don't know	26	43%

In the post-test, 28% of the pre-service elementary teachers accurately answered an open-ended question on cold weather front generation. Most of them focused on the boost of the warm air mass by the cold one: "A cold weather front is created when a cold air mass pushes a warm air mass" (PET27). Some of them tried to explain the phenomenon: "A cold front is created when cold air waves approach land surface due to their heaviness and push warm air waves upwards" (PET30). Furthermore, others mentioned the final physical result: "…the warm air suddenly freezes and shortly precipitates, having as a result rainstorms of short duration" (PET44) (Table 3).

Table 3. Answers about fronts' formation after teaching

How is a cold weather front created?	Num. of p.t. n=60	Percentage
By the boost of the warm air mass by the cold	17	28%
I don't know	15	25%
Various erroneous answers	6	10%
By cold airstreams	6	10%
By barometric systems	4	7%
Due to low ground temperature	4	7%
Due to low temperature	3	5%
By the boost of the cold air mass by the warm	3	5%
Due to air pressure differences	2	3%

However, approximately half of the pre-service elementary teachers denoted wrong causes for fronts' formation. 10% answered that fronts are formed because of cold airstreams, 7% associated fronts with barometric systems, 7% attributed cold front formation to low ground temperature and another 5% made a wider correlation with low temperature. 5% inaccurately described warm front formation, 3% confused front formation with wind formation

and 10% gave various erroneous answers. These results proclaim that the pre-service elementary teachers hold wider problems in the use of Physical Science concepts.

During the interviews pre-service teachers recognized that they confuse concepts and phenomena. At first, they declared that "air masses have high or low barometric system", instead of "air masses generate high or low barometric pressure". Then, they didn't simplify the precise "movement which is created" and its causes. They also didn't discriminate if the "removal" is vertical or horizontal.

Finally, 25% of the pre-service elementary teachers could not respond to the question about front formation in the post-test, a fact that confirms the great difficulties that they encountered in this issue.

Concerning the temperature inversion, 73% of the pre-service elementary teachers ignored the concept and only 3% gave the right answer, namely that inversion occurs when a warm air layer is trapped between two colder air layers (Table 4).

Table 4. Answers about temperature inversion before teaching

Temperature inversion is formed when:	Num. of p.t. n=60	Percentage
A. a warm and a cold air layer run across each other	11	18%
B. a cold air layer is trapped between two warmer layers	3	5%
C. a warm air layer is trapped between two colder layers	2	3%
D. I don't know	44	73%

We expected this percentage to be higher, given that temperature inversion is a meteorological phenomenon frequently appearing into closed basins like Athens and often presented in the media as a cause for high concentrations of pollutants.

Table 5. Answers about the cause of temperature inversion after teaching

What is the cause of the meteorological phenomenon presented in the picture?	Num. of p.t. n=60	Percentage
A. the temperature difference between sea and land	23	38%
B. sudden freezing of the ground during nights without clouds	31	52%
C. the increased temperature of the air	5	8%
D. I don't know	1	2%

In the post-test, pre-service elementary teachers were asked to recognize temperature inversion on a picture and to spot its causes. The results show a great improvement. 52% of the sample selected the right answer compared to 3% before teaching (Table 5).

In a following post-test question, 87% of the pre-service elementary teachers substantiate that they know the consequences of temperature inversion and that they could connect it with air pollution increase (Table 6).

Table 6. Answers about the consequences of temperature inversion after teaching

Temperature inversion occurrence over a city:	Num. of p.t. n=60	Percentage
A. increases air pollution	52	87%
B. increases air temperature	4	7%
C. increases ground temperature	3	5%
D. I don't know	1	2%

The differences between the correct answers concerning the causes (52%) and the effects (87%) of temperature inversion could be attributed to the intent visual impact of the third experiment. Pre-service elementary teachers had been asked to carefully observe smoke produced by a struck match, which accumulated near the ground, so that they could associate temperature inversion with air pollution in a visual way. In reverse, there wasn't an analogous visual impact concerning the causes of the inversion but only verbal correspondence of the cold water in the apparatus with the frozen ground reflecting heat. So, a more complex cognitive process was required to label the outcome "sudden freezing of the ground during nights without clouds".

6. Conclusions

The teaching sequence we have developed seems to promote a better understanding of concepts concerning air mass movements. Taking into account that pre-service elementary teachers had difficulties in recognizing the distinction between horizontal and vertical air mass movements, in declaring their different causes and seemed to conflate causes and effects

in air pressure existence and air movement, our teaching sequence strongly contributed to understanding wind mechanism.

A lower improvement is to be found in weather front formation's understanding, since difficulties in that case seem to be tied with wider problems concerning Science Teaching Education.

Finally, results show that our sample displayed significantly better understanding of temperature inversion in post-tests.

In conclusion, this research points to the need for greater familiarization of pre-service elementary teachers with hands-on Science Teaching, as a prerequisite step for better understanding Environmental Science.

7. References

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