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Developing the concept of the material nature of air through laboratory experiences at primary school level

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Abstract
The purpose of this paper is to present the results of a teaching intervention which aimed to develop the concept of the material nature of air in Greek pupils at the age of 11. The know ledge of the material nature of air is an advantage in learning scientific knowledge about phenomena in which air plays an important role. Such phenomena, according to the current Primary Curriculum are: evaporation, air pressure, combustion, rust formation, photosynthesis, weather phenomena, etc. Our approach is Constructivistic context and our methodology followed that of action research. In the learning tasks in addition to the traditional ones, (weighting balloons, air compression in syringes, etc) we included "meaning clarification", "odd questions", "classification of entities", etc. Our results show that the material nature of matter and its properties (in terms of shape, volume, mass) were attained by pupils, whereas the attainment of goals for the effect of air in phenomena such as evaporation, ice melting, iron oxidation, etc. was less successful.

1. Review of the literature

1.1. *Children's ideas about air*

Pupils' ideas about air have been examined in many aspects and at different ages in many countries. The researchers have focused on aspects like existence, material nature, mass and weight, air pressure, etc. Driver R. et all (1994) resumed these findings for ages 5 to 16. For ages 11 and theirs research findings are briefly presented as follows:

- ***Existence.*** The existence of air is related to sense stimuli, i.e. wind or breathing. Many pupils recognize the existence of air in empty containers and relate the existence to movement in and out (Sere M.G. 1985).
- ***Confusion between gas and air.*** Both air and gas were conceived as non-material entities as having no weight or as having negative weight. *Air is good for health gas is bad*
- ***Material nature.*** The concept of the material nature of air or gas is slowly attained by the age of 15.
- ***Mass or weight.*** The material nature of air is closely related to its weight. So air is conceived by pupils as being very light or as not having weight, or having negative weight as it moves upward. Also, for ages lower than 11, the weight of air is estimated on the basis of its volume.
- ***Volume.*** By the age of 12, 2/3 of pupils appreciate that air occupies part of space and may be compressed.
- ***Active role in phenomena.*** This aspect has been investigated in the case of air pressure and the action of pushing. The action of pushing is accepted by the majority of pupils but less than 50% of the answers show that pressure difference is used in explanations. Pupils' ideas about evaporation and the melting of ice have been examined in terms of conservation of substance or of mass and not in terms of the air as a part of the system where the phenomena occur .The role of air in chemical changes has been examined and pupils recognize that air is necessary for burning. Also pupils are sure that air is necessary for human life although their view is restricted to inhaling-exhaling.
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1.2. *Sequence of concepts in implemented curricula*

Some of the implemented curricula about the teaching of air are:

1. A curriculum for the teaching of air is proposed by M.C.E.T .and F.A.A.C (1997). The sequence of activities is as follows: Air occupies space, air has weight, air has pressure, air moves, heat causes air to expand, air contains moisture, air holds some things up.
2. Properties of air, air velocity, air pressure, force versus pressure (Tufts University, 1996).
3 Properties of air: the teaching of this topic takes place through 19 pupil activities directed by the teacher (Tengwall L., 1994).
4. A curriculum scheme for teaching about air as a material and air pressure was proposed by Brook, A. and Driver, R. in collaboration with Hind, D. (1989). They propose a focus on different concepts for different ages.

2. Methodology

2.1. *Objectives*

The objectives of the program, in line with the Primary Curriculum were: Pupils should be able to describe air in terms of volume, shape, to appreciate that air has mass, and to recognize its active role in phenomena. In addition pupils shou1d be able to differentiate air from gasses and obtain the knowledge that atmospheric air is composed of gasses (oxygen, nitrogen, carbon dioxide)

2.2. *Program evaluation*

In order to evaluate the results of our program and compare the attainment of objectives with the corresponding achievements of children following the usual Primary Curriculum, we went through the following steps:
a) We chose three schools in areas with different social-economic characteristics.
b) On each school we assigned control and experimental classes,
c) Teachers of the experimental classes had a seminar about the teaching strategies, the sequence of lessons and the underlying learning theory.
The pilot phase and all preliminary actions (construction of questionnaires, trial of learning tasks) were carried out in other schools.

2.3. Test construction

Tests were constructed from questions which:

a) Asked pupils to write sentences including words such as solid, liquid, gas, wind, vacuum and matter,
b) Pupils were asked to determine the properties possessed by all solids, liquids, gasses,
c) Pupils were asked to describe possible actions on a solid, a liquid, or a gas and the expended results,
d) Pupils were asked to classify entities such as air, odor, cloud, shadow, dust in two categories: material and non-material,
e) Pupils were asked to offer their personal explanation for phenomena such as rust formation, evaporation and melting in room temperature,
f) Pupils were asked to use a “magic magnifying glass that could make visible even the smallest things” and to observe, with it, a solid, a liquid and a gas. They were asked to draw their observations and to write a small paragraph about their drawings.
g) Pupils were asked to predict the final position of equilibrium of an equal scale balance when the ballon, which was placed on the one scale, deflated. Thew had to shoose one out of three drawings and explains their choice.

In all the above tasks, the target concept (i.e. air) was encircled by questions referring to solid and liquid. We decided to use this form because: a) the pupils’ classification is based on the differences among these three concepts, b) changes in the concept of air, as shown in the pilot phase, go along with changes in the concepts of solid, liquid and gas, c) The four concepts (solid, liquid, gas, air) were included in the same chapter in school textbooks, and we had to teach them in accordance with the control classes. The majority of questions (except for classification into matter, non-matter and the weight of air) belong to the "free response" type. We preferred this type of questions because, as we found in the pilot phase, pupils' responses in multiple response questions were sometimes random.

2.4. ***Time schedule-sample size***

The pre-tests were given before the intervention at the beginning of the school year (September 1995). The first post test was given three weeks after the intervention (December 1995) and the second post-test ten months later at the beginning of the next school year (September 1996). We got pupils' ideas (Pre-test) at the beginning of the 5^{th} grade and the second Post-test was given to them at the beginning of the 6^{th} grade. The number of pupils who completed the three tests is smaller than initially anticipated because some pupils did not take some tests and others moved with their families to other areas during the summer .So, the number of pupils which formed the sample is 119 and 59 of them were taught in experimental classes. Consequently the sample is not a random one and is not completely representative.

2.5. ***Elaboration and evaluation of pupils ' protocols***

A group of experienced primary school teachers with a postgraduate degree in science education examined pupils' protocols and evaluated the attainment of objectives. The evaluation was based on the objectives and the target of question. The categorization of answers formed the following grid:

α) Incorrect-out of context i.e. in contrast with the objectives or out of the context of the question. Examples: *Air is non-material, Air has fixed volume, City air is polluted, today is windy, Gas is poisonous, Air is for breathing, I can do nothing on air, I can see nothing with the magic magnifying glass, or air is depicted as continuous or as continuous containing macroscopic particles,* etc.,

b) *Partially correct,* i.e. part of the answer is incorect or the answer is in-complete. (Examples: *Air is compressible, Gasses do not have stable volume, I can make air move with α fan, I blow air to start α fire,* etc.)

c) Correct, i.e. answer is full and fully correct. (Examples: *Air is α mixture of gasses, Air does not have fixed volume and shape, Air is invisible but has volume and mass. The balance moves this way because the air of the balloon went away and the scale lost weight. I can see tiny particles invisible to the naked eye. These particles are far apart because air is compressible,* etc.)

The answers to different questions were classified into categories according to their similarities. So, answers about air and gas (see 2.3, (a) above) were classified into the following groups:

α) Mαn centered (Examples: *We need air to breath, Clean air is good for our health, Gas can kill people, Gasses are poisonous,* etc.)

b) Metaphors (Examples: *Light as air, Running as quickly as air (Greek has this idiom corresponding (o "run, like the wind" in English)),* etc.

Moreover, due to the origins of the Greek language, air, gas and wind have the same linguistic origin and differ slightly in their spelling. In every day speaking, air is used as an alternative instead of the word wind. So the phrase "the weather is windy" is usual1y replaced by the phrase "we have air", or "air is strong". So some answers were c1assified under the category "metaphor".

c) Paradigms and counter-paradigms (Examp1es: *Oxygen is α gas, air is α gas, Water is not α gas as vapor is, Air is put in car tires, The air in the forest is clean,* etc).

d) Properties (Examp1es: *Air is colorless, Gasses smell bad, gasses are colored, Air does not have any taste, Air does not have any shape,* etc.)

e) *Agent in phenomena* i.e. Air or gasses are conceived as active entities, which can produce effects on other entities. (Examp1es: *Air moves the leaves on the trees, Air moves sailing-boats, oxygen causes rust on iron, CO2 puts out fire* etc.)

f) Passive participants in phenomena i.e. Air or gas were treated as "passive participants" which change under the action of different causes. (Examp1es: *We can compress air, Oxygen is compressed in jars, We can give air any shape we want by putting it in balloons,* etc.)
g) Content, constituents, In such sentences pupi1s refer to what exists in air or gas or the density. (Examp1es: *Air contains dust, air is loose so can be moved easily, gasses contain molecules,* etc.)

After the intervention a new category named scientific description was added in order to cover answers which resemb1e to conclusions or definitions. Such answers inc1ude e1ements from two categories (for examp1e properties and agent). (Examp1es: Air does not have constant volume or shape. We can compress air because it does not have constant volume as 1iquids do, Air is invisib1e but has smal1 weight, etc.)

Answers to the question about the properties of gasses were c1assified into the fol1owing categories:
α) Man-centered, i.e. for breathing,
b) *Tautology,* (Examp1es: *air has the properties of air, gas has the properties of air*,
c) Reference to volume, (Examp1es: *Air does not have its own volume),*
d) Reference to shape, (Examp1es: *Air has the shape of α balloon),*
e) Reference to both volume and shape, (Examp1es: *Gasses do not have their own shape and volume*),
f) Other properties, (Examp1es: *Air is invisible, Gasses have colors, We can not handle air, Gasses have α smell,* Air has mass, gasses have weight, etc),
g) *Active behavior,* (Examp1es: *Gasses flow out from their containers, Air flows freely, Air rusts iron, Air is hot,* etc.),
h) Passive in changes, (Examples: *Air is compressible, Gasses take the shape of the containers,* etc),
i) Content constituents, (Examples: *Air contains dust or particles, Gasses contain poisons, Air contains oxygen,* etc.).

The possible actions on a gas or on air were classified into the following categories:
α) Man-centered, (Examples: *to breath, to inhale and become dizzy,* etc.),
b) *Unable to action* (Examples: *I can do nothing on air, I can release the gas from the container,* etc.),
c) Displacement, (Examples: *To carry gaS in α container, To blow air, To produce an air stream with α fan,* etc.),
d) Physical phenomenon, (Examples: *To compress air, To compress α gas, to change the form of α balloon, To accelerate evaporation,* etc.),
e) Chemical phenomenon, (Examples: *To start α fire, to put out fire,* etc.)

The classification of entities into material and non-material was based on the intended scientific knowledge. So air, odor, vapor should be placed in the category "material" and evaluated as corect.

The answers in the task for the weight of air were classified for both expected outcomes: prediction and explanation. So the categories were:
α) *Correct prediction* when the answer indicated only the correct one,
b) *Incorrect prediction,* when the answer indicated only a wrong prediction,
c) *Correct explanation,* when the answer referred only to a correct response,
d) Incorrect explanation,
e) *Correct prediction or explanation,* when one was missed,
f) Incorrect prediction and explanation when both were incorrect,
g) Correct prediction and explanation.

The involvement of air in the explanations of phenomena was divided into the following categories: *No reference of air, Reference of air.* As in the case of evaporation answers mentioned air as being the receiver of the liquid while in others air was ignored. Also some answers suggested that air might accelerates evaporation. In the case of ice cubes melting some pupils mentioned the cold air in the refrigerator or and the hot air in the room, while others ignored air .In rust formation some answers referred exclusively In air as being an agent while others suggested that humidity and heat are also agents. The " No reference" category was evaluated as "Incorrect", while the "Reference" was evaluated in one oft he other two, according to the objectives.

The answers in terms of the "magic magnifying glass" were grouped in the following categories:

α) Unable to observe anything, (Examples: *I can see nothing, air is transparent,* etc,)

b) Continuous medium i.e. drawings which resemble "clouds" or clouds and lines which represented exhaust-gasses or chimney gasses

c) Continuous medium and macroscopic particles i.e. "clouds" for the medium and dots representing dust,

d) Particles and vacuum, i.e. when dots represented the particles of the air and the space among them represented the vacuum.

Answers classified in a, b, c, were evaluated as "Incorrect". Answers in category d were evaluated as correct.

The above categories were formed without any prejudice and the criteria came exclusively from pupils' answers. An overview of categories shows that they have common elements. The category "Man-centered" has almost the same meaning in the three first tasks and is very close to categories "Unable to act", "Displacement", "Passive in changes". Also the category "Properties" in the first task is close in meaning to the category "Other property" in the second. The active or passive character of air conveyed in the categories "Agent in changes", "Active" and "Passive in changes", "Passive" is confirmed in the categories of the task referring to the action on air. One more element is that "Properties " in all tasks are related to sense stimuli and they are corroborated in the task with the "magic magnifying glass' and in the task for the explanation of phenomena. In these cases air is ignored as a possible agent, or a unseen or cloud like continuous entity.

As far as the above analysis is concerned each answer to every single question was classified in two ways: a) according to the categories, and b) according to the evaluation grid. The evaluation grid was common to all questions and was used to calculate an overall view for every test (Pre and Post tests).

3. ***Pupils ' initial knowledge***

The detailed examination of pupils' answers in the Pre test according to the above described grids lead us to the following conclusions.

1) Meaning confusion: wind and air were confused and the origin of this confusion may be found in every day Greek language. Their properties were also treated very similarly. Air properties were conceived like gas properties and vice versa. Air and gas were differentiated on the ground of human health or their origins. Examples: *Air is necessary for life, air is possibly polluted, air is natural, gas is man-made, gas is poisonous.* In addition pupils wrote many sentences including gasses like O_2, CO_2, H_2, natural gas and this information derived from their technological and cultural environment

2) Air regarded as virtually "non-existent" or its existence was ignored. Example: *An empty bottle contains nothing, it is empty.*

3) Air was differentiated to liquids and solids because of lack of color, of taste, and smell. In addition, according to the pupils, *we can not handle air with our hands*.

4) Solids were treated as being stable and resistant to changes. Liquids were treated as "water-like" entities and as being changed easily. Both liquids and solids differed from air because in the protocols they were mentioned many times: *You can do nothing with air, because you cannot handle air. You can breath air make it move.*

5) The "magic magnifying glass" revealed that: *solids are continuous; liquids are continuous and contain earth resins, salts or microbes. Air is invisible or continuous containing dust and exhaust gases.*

6) Classification into material-non-material shows that the majority of pupils treated air as non-material.

7) When pupils were asked to offer explanations for rust formation, evaporation, melting of ice cubes at room temperature, they did not refer to air as a possible agent for the change.

8) The majority of pupils conceived air as weightless. In cases of correct prediction pupils did not explain their choices or they mentioned the decrease of volume of the balloon. *(The balloon becomes smaller). In cases of incorrect prediction, answers referred to air as being very light and nothing will change.*

The results of the evaluation of each question were summed up in order to offer an overview of pupils' initial knowledge. The results are presented in table 1

Table 1

Pre- Test Evaluation of answers from all Questions			
	Experimental	Control	Total
	Experimental	Control	Total
Out-of-context -Incorrect	52,9%	52,0%	52,4%
Partly correct	28,8%	31,7%	30,2%
Correct	18,3%	16,3%	17,4%
Total	100,00%	100,00%	100,00%

As we can infer from these results pupils' ideas about air are far from the objectives not just in one respect, i.e. weight, volume, active role in phenomena, etc, but in many respects.

4. Teaching intervention

General pattern: Balanced development of the concepts solid, liquid, gas and air through provisional functional definitions (for solid liquid and gas) and re-definitions. Comparisons between groups of substances: similarities and differences, re-definitions. Gas production (chemical phenomena, evaporation, etc) and mixtures. The air contains gasses.

Instructional strategy: Constructivist approach (Driver and Easley 1985)

4.1. ***Sequence of lessons***

1) Classification of entities into "solids", "liquids", "gasses" (The set of substances for classification included pupils' stereotypes (i.e. stone, water) and non-prototype entities such as empty bottles, bottles filled with odors, liquids which evaporate quickly like benzene, liquid glue, ice cubes, naphthalene) Goal: Provisional definition for solid, liquid and gas. Weight measurement for solids, liquids, drops and granules.
2) Action on "solid", "liquid", "gas" and its results. Properties, which discriminate "solid" from "liquid" and "gas". The laboratory session offered chances for experimentation with prototypes and non-prototypes. The measurement of volume for "solid", "liquid" and "gas". Definitions for solid and liquid. Provisional definition for "gas".
3) Other "gasses": odor, vapor, oxygen, CO2. Laboratory activities and demonstration experiments. Goals: Air is a "gas" composed of different gasses. Similarities and differences between air and gasses.

In 1 and 2 above the terms gas and air have provisional definitions and in 3 the terms are clarified and the definitions coincide with the aimed at.

4.2. ***Learning tasks***

The learning tasks, which were used, are the following:

- Writing (phrases, paragraphs) and meaning clarification. Sentence writing, word meanings, meaning classification. Specification of properties of "solids", "liquids" and "gasses".
- Classification of substances in "solid", "liquid" and "gas". Laboratory activity, written reports discussion in classroom.

- What can you do on a "solid", a "liquid" or a "gas"? What are the results, laboratory activities, monitored experimentation reports? Discussion of reports. Determining the characteristics, which differentiate solid from 1iquids and "gasses".
- Production and use of "gasses": odor, vapor, CO2, oxygen. Laboratory activities and demonstration experiments.
- "Communicate what you mean" exercises. Those responding to the phrases or paragraphs were other pupils, tradesman or craftsmen in pupils' neighborhood
- "Odd questions and riddles" Teachers asked their pupils questions such as: "Could you bring me some air?" "Something around us is being used constantly but never runs out. Could you name it?". "Everything around us has its limits. Could you suggest the limits of air?". " An overweight person is on a bathroom balance reading his/her weight. What will happen if he/she breathes out as much as he/she can?" The goal for such questions was to reinforce pupils' curiosity and confront them with every day sayings about air.

The main differences between the experimental intervention and the one of the official curriculum are the following:
A) The theoretical perspective, in creating the sequence of lessons and the teaching strategy i.e. Constructivism,
B) The development of the concept of gas and then the formation of the concept of air. In the official curriculum the sequence is reversed. Air is studied and its properties, in terms of being, occupying space, having weight being compressible, etc. Then air is analyzed into gases, O_2, CO_2 e.t.c. with the help of demonstration experiments.
C) Phenomena in which a “gas", according to pupils' initial knowledge, is produced were included in the experimental intervention while in the official curriculum they are studied under topics like Thermal phenomena and Chemical phenomena.
D) The learning tasks of the experimental intervention had diversity and according to pupils were " pleasant and fun producing" especially the " odd questions, the riddles and the action on materials".

5. The results of the intervention

5.1. ***The attained knowledge*** (post test 1)
The analysis of protocols from the 1st Post test shows changes not only in the categories but also in the evaluation. The changes in the categories lead to the following results:
1) The meaning confusion between air and gas was resolved, especially among the pupils of experimental classes. The distinction between the two words was expressed in the sentence writing task and the practical task. In sentence writing the majority of sentences with the word "gas" were put in the categories "Paradigm" and "Properties". The sentences for the word "air" were classified in the categories "Scientific description", "Content" "Properties", "Agent". The results of the practical task show an increase in the number of sentences in the category "Physical " or "Chemical phenomenon" and a decrease of the cases in the "Man-centered" ones. The number of answers, which shows incapability of action on air, was also decreased.
2) The task concerning the weight of air revealed that the majority of pupils in experimental classes gave answers that were classified in the category "Correct prediction and Explanation".
3) The practical task showed that percentages of categories "Man-centered", "Displacement", "Incapable action" were decreased.
4) The task about the properties of air showed that for both experimentalI and control classes, the volume and the shape were the major characteristics which discriminate solids, liquids and air .In experimental classes the majority of pupils from mentioned both volume and shape while in control classes the majority focused on one of them.
5) The task of the "magic magnifying glass" indicated that pupils in experimental classes imagined air as constituted of tiny particles and of empty space. These particles resemble

molecules and the empty space resembles the vacuum. Very few descriptions (15%) referred to the word vacuum but appeared more frequently (25%) to compressibility of air.

6) The task of explanations indicated that air was mentioned as agent in 30%-55% of cases. The 30% comes from the ice melting and the 55% from rust formation.

The changes above described were expressed in the evaluation of answers. The results of this evaluation for all questions are presented in table 2.

Table 2

Post- Test Evaluation of answers from all questions			
	Experimental	Control	Total
	Experimental	Control	Total
Out-of-context -Incorrect	5,4%	41,9%	23,5%
Partly correct	25,5%	26,2%	25,8%
Correct	69,1%	31,9%	50,7%
Total	100,00%	100,00%	100,00%

Comparison of the percentages in tables 1, 2 shows that experimental classes attained the objectives to a greater extent than the control classes.

5.2. ***The duration of attained knowledge (post test* 2)**

Ten months after the 1^{st} post-test and after the summer vacations, pupi1s completed in the 2nd post-test. Between the 1st post test and the end of the school year , pupils in experimental and control classes continued their lessons according to the official curriculum. So, a few subjects from the experimental curriculum were used in other contexts like the physiology of respiration, photosynthesis, study of the weather, etc. As pupils were taught the same subjects and used the same school textbooks, the influence on their knowledge as described in 5.1 should be treated as equal for both control and experimental classes. The changes which were registered in the 2^{nd} post-test were the following.

1) In the writing a sentence task, pupils from the control classes, in the majority of answers, used paradigms for the word gas but stepped back to "man-centred" answers for the word air. In contrast, pupils from the experimental classes, referring to air, gave less "Man-centred" answers and were almost consistent for the categories "Properties" and "Agent"

2) The distinction between air and gas was clear for both groups and the main difference focused in the "Content" and the "Properties" for air and the "Paradigms" for gas.

3) Pupils in the experimental classes referred to the properties of air in terms of volume and shape in higher percentage (37 ,9%) compared to the control ones (1,8%). The majority of pupils from the control classes focused on "other properties", i.e. transparency, taste, color, and the volume, i.e. compressibility of air .The content and the constituents of air were mentioned seldom by pupils from the control classes (8,8%) while the percentage was low for the experimental classes (20,3%)

4) The action-on-air task showed that the "man-centred" answers increased for both groups but the percentage in the control group was lower (10,5% for the experimental, 39,2% for the control) The "Incapable-of-action " category revealed in control classes and the "Physical " or "Chemical Phenomenon" categories were low in control classes.

5) The classification into "Material" and "non-Material" indicated that pupils from the control group revert to their initial state (18,3% material). Pupils from the experimental group showed a smal1 improvement relative to the 1^{st} post-test and the percentage rose to 96,6%.

6) The task about the weight of air showed that in both groups the category "Correct prediction and explanation" was over 50%, 78.9% for the experimental and 51,7% for the control. Relative to the 1^{st} post-test the control group showed improvement. This might be explained as an effect of the subjects taught after the 1^{st} post-test.

7) The "magic magnifying glass" task showed that pupils from the experimental classes improved their particle ideas about air although the particles lacked properties like movement and random distribution in the drawings. Compared to the 1^{st} post-test we found that the particle drawings increased but their closeness to molecules decreased. Pupils from control

classes revert to categories "Continuous" and "Continuous and macroscopic particles", or their particle ideas for air were incorrect in relation to scientific understanding of molecules.
8) The references to air in phenomena decreased slightly (from 55% to 45%) for the experimental group and went down to 10% for the control

The evaluation of answers for all questions is presented in table 3.

Table 3

Post- Test Evaluation of answers from all questions			
	Experimental	Control	Total
	Column%	Column%	Column%
Out-of-context -Incorrect	12,6%	39,0%	25,6%
Partly correct	28,7%	26,3%	32,5%
Correct	58,7%	24,7%	41,9%
Total	100,00%	100,00%	100,00%

The comparison of tables 1, 2 and 3 , shows that pupils from the experimental classes attained the objectives in higher percentages than the others. In addition the duration of this knowledge extended at least to the next school year .

6. Conclusions and limitations

A statistica1 exanimation of the above resu1ts with the chi-squared test proved that the differences between the experimental and the control group were significant at the leve1 of 0.05, for the post tests and for the majority of questions. Except for those referring to properties and the weight of air for the 1st post-test. in these cases both groups got similar results. The comparison of resu1ts, between pre test and 1st post-test, about either group of air as an agent in phenomena showed no significant change for both groups, although the resu1ts were better for the experimental group. The changes described with the "magic magnifying g1ass", between pre test and 1st post test, were significant for the e experimental group and the idea of molecule was approached.

In case of the results referred to in 5.1 and 5.2, it should be taking into consideration:
a) The two interventions had the same objectives but were different in many points, as described in 4.1 and 4.2,
b) The sample was not random or representative,
c) The learning outcome of 1st post-test was affected by the subjects taught up to the end of the school year and hence the 2nd post test does not describe what remained after ten months.
These limitations prevent us from generalizing from Greek primary pupils at the age of 11.

What our results do indicate is that:
a) The concept of air is related to other concepts 1ike solid, 1iquid and gas, vapor, and this interrelation should be taken into consideration for curriculum development,
b) the conceptual change about air is related to changes occurring in the other concepts,
c) the concept of gas was easy to grasp and improved over time as a function of an increase in genera1 knowledge about gasses, and
d) the concept of gas could function as a basis for the development of the concept of air.

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