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THE PUPIL AS A REFLECTIVE THINKER: A STUDY IN THE ELEMENTARY SCHOOL

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INTRODUCTION

Learning as a conceptual change is today, in the science teaching and learning process, an idea increasingly accepted by researchers and teachers.

Although there isn't yet a theory of conceptual change unanimously accepted, many researchers propose different teaching models to promote a conceptual change in the classroom (e.g., Posner et al., 1982; Cosgrove and Osborne, 1985; Gil Perez and Carrascosa, 1985; Driver and Oldham, 1986; Giordan, 1989). Some of them examine the conditions under which a concept is accepted, retained, reorganized or changed, suggesting, simultaneously, activities for the school teaching. This leads to a "constructivistic pedagogy" (Cheung and Taylor, 1991), where one of the main goals is to facilitate the change of personal and diverse ideas of the students to the socially constructed and accepted knowledge of science. In this process a reflective dimension of learning seems to be regarded as essencial (Gil Perez and Carrascosa, 1985; Harlen, 1985; Hashweh, 1987).

THE REFLECTIVE ATTITUDE IN THE CONCEPTUAL CHANGE PROCESS

Psychological and epistemological reasons can be raised to justify the inclusion of reflective activities in the teaching and learning process of science. In the former, we remember Vigotsky (1979) and Piaget' s (1977) positions about the importance of the learners becoming aware about the knowledge reorganization/development. The second set of reasons are extracted from the concept of "epistemological rupture with the commonsense", stressed by Bachelard (1986), or, more recently, "the change of a research programme", mentioned by Lakatos (Lakatos and Musgrave, 1986).

In another context, more related with the teaching and learning in the classroom, several authors point out the importance of increasing a reflective attitude among students as an essencial condition to promote a real conceptual change. Because they think that in the origin of the students' alternative ideas is a "superficial methodology" (Gil Perez and Carrascosa, 1985), or a "commonsense epistemology" (Hashweh, 1987), these researchers mention the need of developing teaching strategies which can lead the students to face problems in a more reflective and critical way.

Harlen (1985) also refers the importance of developing a reflective and critical attitude even among young students. "The value of developing this attitude is clearly that it increases the potential learning, of the processes and ideas of science, from each activity (...) part of this can be satisfaction of finding better ways of investigating and more powerful ideas ..." (p. 50).

REFLECTIVE ACTIVITIES IN THE TEACHING AND LEARNING PROCESS: A PROPOSAL

Some of the teaching trends previously mentioned (specially Posner et al., 1982; Gil Perez and Carrascosa, 1985; Giordan, 1989) were a starting point to a teaching approach (Sequeira and Duarte, 1991), later reorganized, where the students participation in reflective activities is an essencial step.

The diagram of Fig. 1 illustrates, in a simplified way, the incorporation of reflective activities in a teaching method which can promote a conceptual change. According to this project, the learning of science demands a continuous recycling of the experience and the conceptualization through reflection. In other words, the reflection is the "bridge" between the experience and the theoretical conceptualization.

The process develops in four phases. Each of them starting from a more controlled situation to a bigger students' autonomy. Although different, all of the phases have the same goal: to encourage the learners' conceptual change.

Phase 1: This phase focuses on the understanding of the ideas and situations; one tries students to realize the way they think and the different perspectives they have.

Phase 2: Just the reflection about experience can seriously lead to the reorganization of ideas. Learning science in a constructive way demands not only the exploration of students' previous ideas (through formulation/verification of hypotheses, handling of problematic situations ...), but also a reflection about the solutions achieved, comparing predictions with results, questionning the procedures and the ideas...

Phase 3: The reflection about the adequacy of the new knowledge to different situations increases its usefulness and facilitates the reorganization of the students' ideas (Posner et al., 1983).

Phase 4: Learning monitoring promotes the students' autonomy, helps them to both improve their own views as learners and to be able to use their learning potential more fully. In this stage one tries to make the students to reflect about the changing/reorganization of ideas and evaluate their own progress.

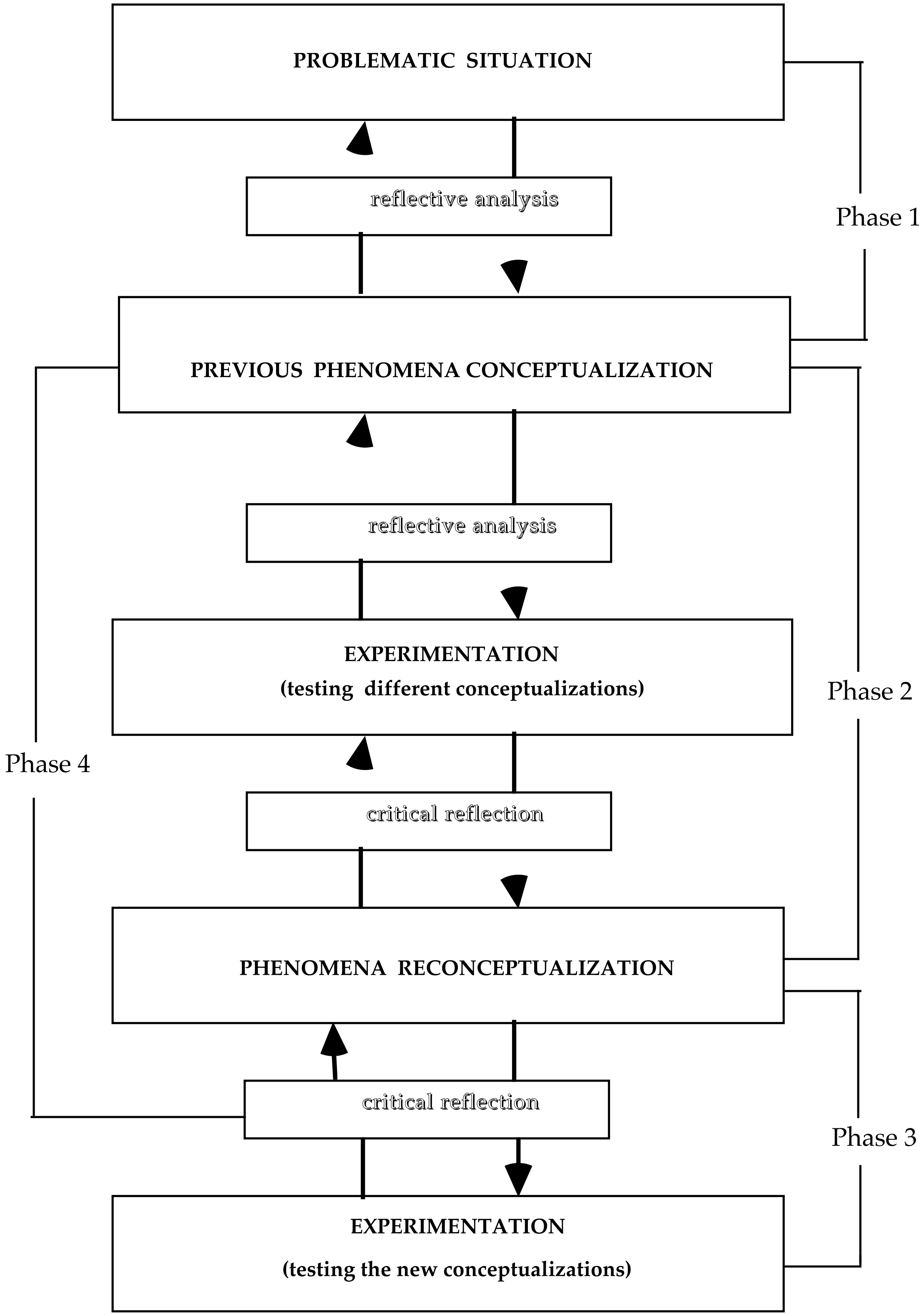

Fig. 1

Simplified diagram about the integration of reflection activities
in conceptual change teaching

Based upon some of the theoretical considerations we have already briefly referred to, the main objective of the present study was to evaluate the efficiency in the promoting pupils' conceptual change, of a model of teaching in which the activities were chosen in order that the pupils explicit, explore and reflect upon different ideas and procedures.

METHODOLOGY

Sample:

a) Pupils - ten classes (208 subjects) of pupils in their 5th elementary school year, belonging to three different schools. From the ten classes four were the experimental group, other four the control group and two the control group of the pre-test effect. When selecting the classes we tried to take into account the following criteria:

- the classes should be homogeneous in what respects the socio-economic level of the pupils.

- the classes should be taught by trained teachers and, if possible, teachers with some years of teaching experience in Natural Science.

b) Teachers - seven teachers took part in the study: two were teaching in the experimental classes, three in the control ones and two in the control classes of the pre-test effect.

Many were the teachers we have been in contact with, but several did not want to take part in our experiment. Therefore, the group we could set is formed by teachers with a similar professional and academic training (all of them had a "Licenciatura", a five year degree, on subjects related to natural science; all of them have done teacher training), but with different number of years of teaching experience.

In table 1 we present a general characterization of the sample of pupils in the study, concerning the number of pupils per class, their average age, their socio-economic level and their teacher.

Table 1

Characterization of the sample of pupils

(N=208)

Classes	n	Mean age (years)	Socio-economic level	Teacher
E1	20	10.6	PS1+PS2	T1
E2	19	10.5	PS1+PS2	T1
E3	19	10.5	PS3+PS4	T2
E4	23	10.7	PS3+PS4	T2
C1	19	11.0	PS1+PS2	T3
C2	19	10.8	PS3+PS4	T3
C3	23	10.7	PS3+PS4	T4
C4	21	10.8	PS1+PS2	T5
Cp1	24	10.6	PS3+PS4	T6
Cp2	21	10.4	PS1+PS2	T7

Note: E - Experimental group PS1+PS2 - high socio-economic level
C - Control group PS3+PS4 - low socio-economic level
Cp - Control group of the pre-test effect
T - Teacher

Implementation of the teaching proposal

The teaching model we devised (which is included in the diagram in figure 1) was implemented for the teaching and learning of the curricular topic "Corpuscular Model - Properties and Transformations of Matter". This implementation in the classroom included three phases:

1) Training of the teachers: before beginning to teach this topic, one of the authors of this study organized several workshops with the two teachers responsible for teaching the experimental classes. In these workshops they discussed our proposal which had been presented to them beforehand in written form. This proposal included a theoretical approach to the problem of alternative ideas and conceptual change, as well as a teaching plan with suggestions for the topic referred to.

2) Application of the pre-test: before beginning teaching, a pre-test was given to the pupils of the sample. This pre-test aimed at evaluating the starting point of the different classes, including the diagnosis of the pupils' alternative ideas on the contents they were about to study.

3) Implementation in the classroom: this stage began with the teaching of the topic we were investigating, and took about 11 weeks (33 lessons). One of the authors of this study was present in all lessons of the experimental classes, as a participating observer, and in all lessons of one control class. All the observed classes were video-recorded.

During the teaching sequence, the lessons of the experimental classes were analysed both by the observer and the teacher, which allowed readjusting the proposed methodology, according to the evolution of the pupils themselves.

Characterization of the "traditional methodology"

The evaluation of the proposed model was made through the comparison of its efficiency in promoting pupils' conceptual change with the methodology normally used by the teachers (here named "traditional methodology"). This fact determined the need to characterize the methodology used in the control classes, in terms of its similarity to the proposed model. This characterization was carried out by direct observation and video-recordings of the lessons of one of the control classes, with the help of an observation sheet specially designed for that purpose.

From the analysis made we concluded that the "traditional methodology" was very different from the proposed methodology, mainly in aspects we regarded as essential, such as:

- activities intentionally directed towards the explicitness and testing of the pupils' ideas were not carried out;

- activities leading to the pupils' reflection on their performance and progression were not carried out;

- the experimental activity turned out to be the confirmation of the ideas the teacher wanted to convey (recourse to demonstration or the use of protocols);

- the dialogue became a "question-answer" activity, very much teacher-centred;

- great number of the activites undertaken were information-centred; this information was directly "explained" by the teacher or with the help of the textbook.

Although the characterization, here briefly presented, has been based on the lessons of a single teacher (the only one who authorized classroom observation), from the informal conversations we had with the teachers of the control classes, we could infer that these teachers' practices are very similar to the characteristics above mentioned.

DATA GATHERING

The data were mainly gathered through classroom observation and use of a questionnaire as pre and post-test.

Questionnaire: In its final version the questionnaire included 30 questions concerning the topic of the syllabus - "Corpuscular Model - Properties and Transformations of Matter". These questions were distributed in four thematic groups: I - Conservation (of volume, quantity of matter and substance); II - Properties of matter; III - Physical tranformation of matter; IV - Structure of matter. The questions were about the solid, liquid and gaseous states the matter.

Its application as a pre-test was made about 15 days before beginning to teach the topic; as a post-test it was applied about a month after the conclusion of the study.

Whenever the pupils' answers raised any doubt about the interpretation of the questions, we complemented the questionnaire with an interview.

DATA TREATMENT AND ANALYSIS

The data were analysed bearing in mind the purposes of the investigation, resorting to varied procedures aiming at increasing the validity of the results.

1. Evaluation of the starting point - three procedures were used in order to evaluate the starting point of the classes and of the groups:

a) Evaluation of the performance based on the "mean score" obtained in the pre-test - the answers were classified according to their content, in two mutually exclusive categories: "accepted answers" and "non-accepted answers". The "accepted answers" were defined according to a previously established criteria in accordance with the information in textbooks for this learning level. In the category "non-accepted answers" we included answers whose content totally or partially disagreed with the "accepted answer"; we also included in this category "don't know" and the absence of opinion. Based upon the "mean score" the different classes were compared through the t' Student test ($p < .05$)

b) Determination of the "mean" percentage of "accepted answers", concerning each of the themes included in the pre-test - owing to the diversity of contents included in the questionnaire, we thought that this procedure would allow to obtain a more detailed "performance profile" in the groups concerning the different themes of the questionnaire.

c) Identification of the predominant alternative ideas among the pupils - with this purpose in mind we carried out a content analysis of the answers given by the pupils, following three stages: (1) concerning each question we grouped the students' answers, in such a way as to get lists of similar answers; (2) we designed a description of the fundamental ideas present in the pupils' answers, in a way as to get a "typical answer" which would contain the ideas of all students; (3) we analized these "typical answers" to identify some alternative ideas, which we thought were underlying those answers.

2. Evaluation of the pupils' conceptual changes - the use of the procedures described earlier, applied to the pupils' answers in the post-test, allowed our evaluation of the pupils' performance after teaching. The comparison of the pre-teaching and post-teaching performance allowed us to infer the extension of the conceptual change in the pupils of the experimental and control groups.

ANALYSIS AND DISCUSSION OF THE RESULTS

For reasons related to the limits imposed to this paper, we present just some of the results obtained.

1. The evaluation of the conceptual change based on the performance of both the experimental and the control groups.

Figures 2 and 3 show the " performance profiles" of the experimental and the control groups before teaching (BT) and after teaching (AT), respectively.

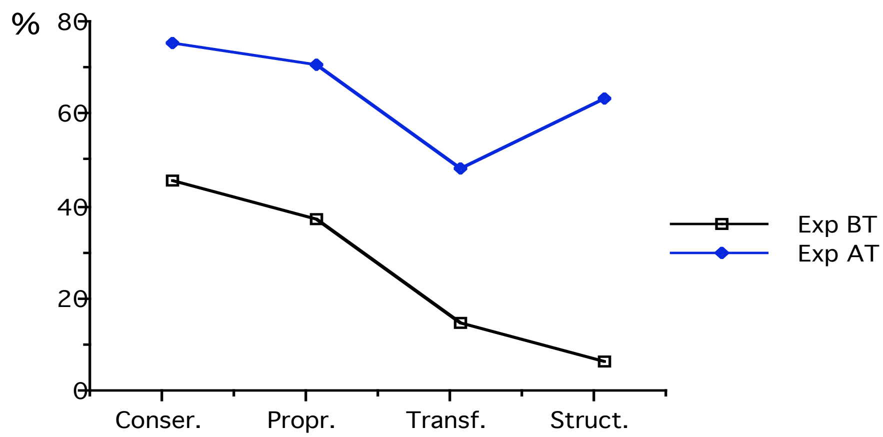

Fig. 2

Experimental group's performance in the four thematic areas of the questionnaire

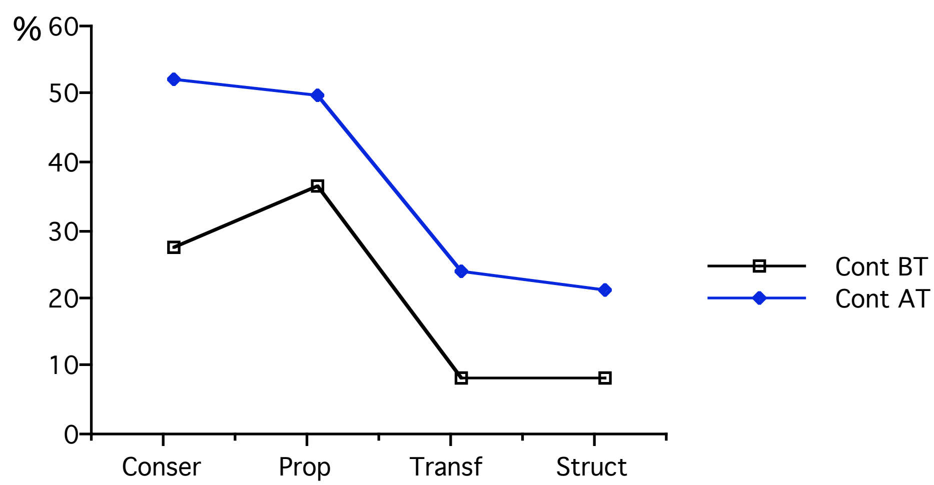

Fig. 3

Control group's performance in the four thematic areas of the questionnaire

In a first analysis of the figures we verify that both groups show very different profiles in the pre-teaching situation and in the post-teaching situation. These results do not only show that the teaching did succeed in both groups - a proved fact through the comparison of the "mean score" (the values for the t' Student test were significant for $p < .05$) - but they also show that this success concerns all thematic contents included in the questionnaire. Nevertheless, the analysis of figure 4 shows that the distance between both groups is greater in the post-teaching situation (a fact which is proved by the values for the t' Student test, $p < .05$) than in the pre-teaching situation.

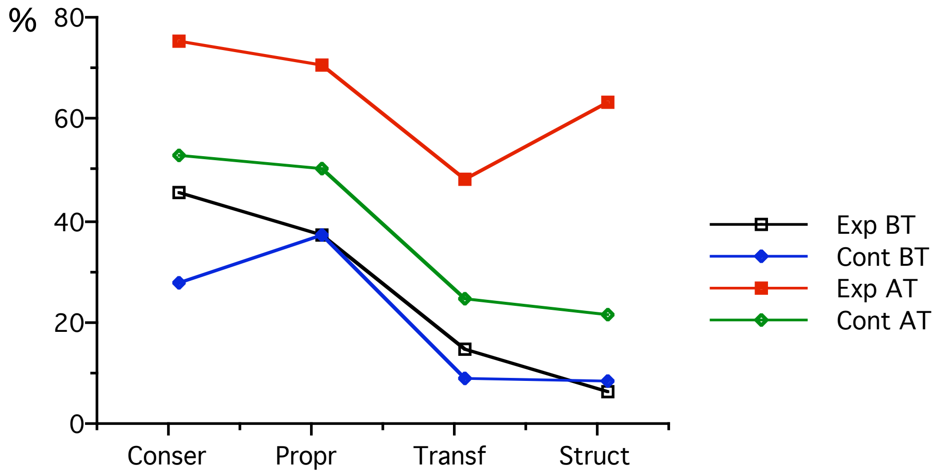

Fig. 4

Experimental and control groups' performance in the four thematic areas of the questionnaire

The profiles presented point clearly to a diferential post-teaching behaviour in both groups. These results are reinforced and clarified by the data in figure 5, which presents the "profile of success" determined by the difference between the "mean" percentage of "accepted answers" obtained after and before teaching (AT-BT).

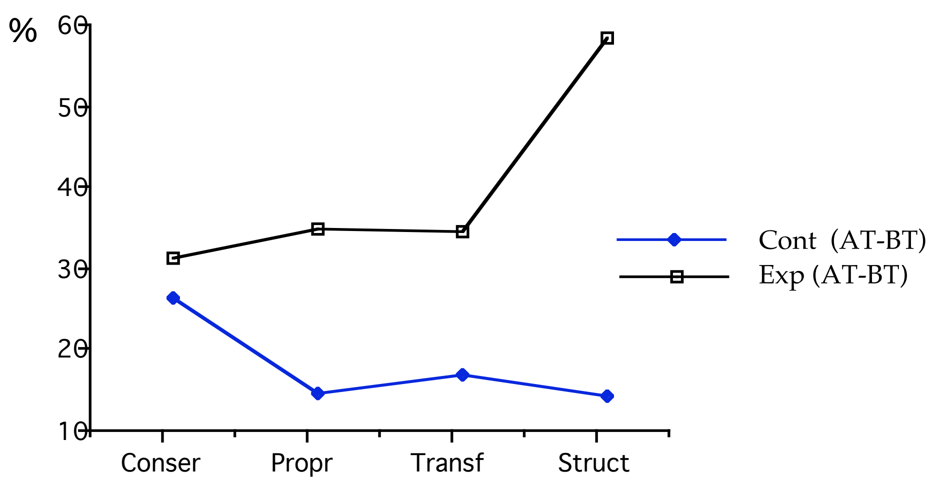

Fig. 5

Experimental and control groups' "profile of success" in the four thematic areas of the questionnaire

The analysis of the results presented in figures 2, 3, 4, and 5 shows a better performance in the experimental classes, in comparison with the control classes, in all themes of the questionnaire. These findings support the assumption that the proposed methodology has turned out to be more effective in promoting pupils' conceptual change than the "traditional methodology" normally used in the natural science classroom.

2. Analysis of the conceptual change based on the evolution of the pupils' alternative ideas

The content analysis of the pupils' answers before and after teaching showed the existence of different situations:

a) The answers in the pre and post-teaching situations were the same;

b) The answers in the post-teaching situation reveal a juxtaposition of a scientific terminology to the answers in the pre-teaching situation, without having been a real change in their meaning, as shown in the following examples about "air pressure " and "water evaporation":

" ... air doesn't exert force because it is free" (answer in the pre-teaching situation) and "... air doesn't exert force because the particles are free" (answer in the post-teaching situation)

"... vapor is air" (answer in the pre-teaching situation) and "vapor is made of molecules of air" (answer in the post-teaching situation).

The word particle is used, in the above mentioned examples, but this doesn't mean that there was a change in the original alternative ideas identified: "air doesn't make pressure when in the 'open air' situation" and "there is no conservation of the water when it evaporates". However, we may consider that, concerning the conceptualization of the structure of matter, there could have been a change from a continuous conception to a discontinuous conception.

c) In the post-teaching answers, pupils used newly learned ideas to support an idea they had before teaching. Examples:

"...there is more air because de volume increased, spaces between particles increased".

Pupils kept in mind the idea that in dilation particles move away. They acquired this idea when this topic was taught. Here, they use it to support the initial conception of "non conservation of the quantity of air in dilation". Therefore, they still make a confusion between mass and volume.

In short, we may say that the variety of answers and alternative ideas identified in the post-teaching situation, some of which present a great similarity between students from both experimental and control groups, clearly reveal the difficulties that many students face in the process of conceptual change, even when using teaching strategies taking such ideas into account. However, from the analysis of most frequent responses before and after teaching, it seems to emerge the existence of an evolution in students' ideas specially those connected to the conceptualization of matter. Thus, the idea of continuous matter (prevailing between students in the pre-teaching situation) seems to evolve into a corpuscular model, simplified and static, tending to apply macroscopic characteristics to particles, and into an analitic and incomplete model where the notion of interaction between particles takes no place. This evolution is more frequent in the experimental group than in the control group.

The results presented before (which consist of a small sample of the analysis performed) allow us to come to the following conclusion: the experimental teaching approach, where some effort was put in leading the sudents to explore their own alternative ideas, as well as making a reflection over the performance and progress in learning, seems to be more effective in promoting the conceptual change in students rather than the "traditional teaching approach". In spite of this, we must point out at least one limitation of this study: an evaluation of the proposed model was actually not carried out in what concerns the change in students' attitude facing the act of learning. Some factors seemed impeditive to perform this evaluation: the time that the teaching experiment took (only about 33 one hour classes) was clearly insufficient to allow us to correctly evaluate any change in the students' attitude; in addition to this, we have to consider the fact that it is in the 5th grade when the students begin a more sistematic study of Natural Science. But from both direct observation and video-recording of the classes, it was possible to notice that: as the teaching program was developing, the students were becoming more deeply involved in the learning tasks and more careful in their analysis and answers to the problematic situations. They also changed into a more open mind in order to consider diverging ideas and they showed more tendency to handle the self-analysis of their own performance and progress.

CONCLUSION

Inherent to the whole study, was the conviction that the child, as every human beeing, enjoys learning. By making easier the reconstruction of the scientific knowledge, school should keep that willingness to learn well alive by stimulating the curiosity and desire of exploration, not forgetting to help the pupil to become a reflective thinker.

This study did not aim to suggest a valid methodology for any situation. Above all, we intended to investigate a process to facilitating students in their task of learning scientific knowledge. Although a careful analysis about its procedures and results allows us, surely, to reformulate some aspects, we consider that it is possible and desirable, that the proposed model should be implemented in other scientific areas.

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