Teaching the topic of the Particulate Nature of Matter in Prospective Teachers Training Courses

Panagiotis Kokkotas and Ioannis Vlachos, University of Athens, Greece
Vasilis Koulaidis, University of Patras, Greece

This article presents an attempt to improve teaching-learning strategies for science as addressed by prospective teachers in the Department of Primary Education of the University of Athens. The aim of the proposed strategy is twofold: to promote the constructivist aspect in science teaching-learning and to improve prospective teachers' knowledge in the particulate nature of matter. Prospective teachers were confronted with pupils' ideas about matter and its transformations as they are described and explained by the molecular theory of matter. They were asked to evaluate pupils' explanations about the states of matter and changes of state as if they were the pupils' actual teachers. Moreover they were asked to discuss the origins of pupils conceptions and to propose appropriate interventions for classroom activities. The results show that prospective teachers share a number of misconceptions with pupils' and that when they "act as real teachers" they willingly revise their relevant ideas and accept a more constructivist approach to science teaching.

Introduction

This presents an attempt to teach the topic of the particulate nature of matter to prospective primary teachers following a constructivist approach. The constructivist approach is based on the premise that science is a human construction. Moreover, this approach implies that scientist's personal ideas are debated within the scientific community so that a consensus is established. This consensus constitutes one of the basic dimensions of the accepted paradigm. As far as learning is concerned, the constructivist approach accepts that children construct or reconstruct or change their representations about the environment (natural, technical and cultural) in which they live, mainly through three processes: the interaction with adults, with their peers and their personal experiences. Accordingly curriculum treats pupils as possessing a «naive science», which should not be ignored or rejected. (Millar & Driver, 1987). On the contrary, this «naive science» should be activated through well-studied tasks that help pupils discover for themselves that their opinions can not convince their peers or disagree with the experimental results (Dreyfus et al., 1990). So, they reconstruct their ideas towards a representation closer to the scientific one. The traditional distinction between "Correct" (i.e. the scientific ideas) and "Incorrect" (i.e. any non-scientific ideas) children's answers to teachers' questions, is not used by constructivists for children's answers, as the last depict children's cognitive efforts and their "naive" science. In this way we avoid: a) picturing science as exact and irrefutable and b) the emphasis on the authority of those who possess the scientific knowledge. It should be stressed that we lack a widely accepted description of the learning process. In cognitive science, learning is portrayed as "conceptual change" which sometimes is described as "continuous or evolutionary" or "discontinuous or revolutionary" (Duit 1994). Although a full description of learning from a constructivist's point of view is missing, the benefits of such approaches are appreciated even by researchers who criticise constructivism (Solomon J. 1994, Osborne J. 1996).

Initial prospective teacher training aims to teach them not only subject matter knowledge but also teaching methodologies. The science curricula for primary education include basic scientific concepts and processes and a large number of phenomena.. In the programme of the Department of Primary Education of the University of Athens an attempt was made to incorporate research findings into the teaching of prospective primary school teachers. They are introduced to the constructivist approach for science in the fourth year of their studies. This curriculum includes: a. lectures, b. observations and discussions of teaching activities in school classrooms, c. small projects in collecting, classifying and commentating on pupils' ideas, d. supervised student teaching practicum, and e. prospective teachers experience constructivist approaches for specific concepts or phenomena in a constructivist teaching and learning environment. The last process aims to offer prospective teachers constructivism in action experiences in classrooms from a learner's point of view. The prospective teachers form small groups and work as a class according to a constructivist strategy in order to change their conceptions about basic scientific concepts or phenomena. The main topics in Physics and Chemistry are: force, energy, light-shadow, heat-temperature, conservation of matter, particulate nature of matter, the buoyancy and the relevant phenomena. In addition elements from biology such as the structure of the flower, germination, sprouting, growth, etc. are included.

The topic particulate nature of matter, was chosen as the most appropriate issue to focus our study on, for the following reasons: a) the topic is very significant in the sciences, specifically in Chemistry and Physics ; b) the topic is included in current Curriculum in Sciences of the Primary Education ; and c) it is extensively covered in the Secondary Education Curriculum, so prospective teachers have studied it.

Review of the literature

A review of the relevant literature indicates that :

a) As reported by Piaget and Inhelder (1974, 1941), the idea that matter is made from particles whose properties resemble those of atoms (atomistic idea) begins to develop from the age of ten. Factors like age, cultural and social environment could influence the development of the atomistic idea as well as the conservation of matter (Slone and Bokhurst 1992).
b) Other researchers (Brook et al. 1984), suggest that students in secondary education hold the view that matter is continuous (not made up from discrete particles) and accept the particle model (atoms, molecules) in very limited contexts.
c) The nature and the behaviour of particles within the conceptual frameworks of children and students are different from the scientifically accepted ones. It is usual for students to attribute macroscopic properties such as melting, dissolving, expanding, to the microscopic particles. (Brook et al 1984, Andersson 1992). The particle model is combined with the children's continuous model producing synthetic models. Thus, children depict the matter as continuous containing the particles of a substance. (Anderson 1992, Nussbaum and Novic 1978). Additionally, children are likely to reject the idea that molecules of air are moving in an empty space.
d) The ideas stated by students when confronted with transformations of matter in physical or chemical phenomena can be classified in the following categories (Andersson 1992) 1)Disappearance (evaporation of water), 2) Displacement (drops of water formed on the surface of a bottle filled with cold water come from the interior), 3) Modification (pupils explaining the formation of vapour, when water is boiling, claim that the water is modified into vapour), 4) Transmutation (regarding vapour as different substance from water), and 5) Chemical interaction (the bubbles observed when water is boiling are made of oxygen or hydrogen, viz. regarding a physical phenomenon as a chemical phenomenon).
e) Pupils' responses to questions regarding the changes of matter can be classified, under the criterion of what is conserved and what alters, into the following categories: 1. form, 2. arrangement, 3. location, and 4. making. The first category dominates in descriptions, especially when pupils are confronted with non-familiar systems, and usually operates at the macro-level. However pupils resort to the last categories in order to explain the changes, operating at the micro-level when discussing familiar systems (Koulaidis and Hatzinikita 1996)
f) Every day science and language are related to pupils' ideas and withstand formal teaching methods. (Johnstone 1992)
g) Existing textbooks and especially the representations of the particulate nature of matter can produce misconceptions (Andersson 1992). Indeed, pupils' representations about the structure of matter are along the same lines with the way this topic is pictured by the school textbooks. More specifically, in Greek science textbooks for primary schools: 1. matter is continuous and static, 2. molecules are small particles formed by successive partitioning of matter and thus they keep their macro-properties such as hard, soft, etc. , and 3. description and explanation are given at micro-level (which is understood in terms of size) when dealing with familiar systems consisting of a solid and a liquid (Koulaidis and Hatzinikita 1966)
h) Teachers and prospective teachers have ideas which are not scientifically accepted. Also many of these ideas are similar to those held by children. (Kruger and Summers 1988)
i) Research findings relative to Greek prospective primary school teachers indicate that even though they have been taught Physics and Chemistry during their secondary education years, they retain ideas which are different from the scientifically acceptable. (Kokkotas & Hatzinikita 1994, Stavridou et al 1994,.

These results, although briefly presented, show that :

1. Pupils' ideas about matter and its transformations (physical or chemical) are stable and they survive even after the intervention of formal education (see points b,c,h,i, above),
2. the scientific particle model of matter is combined with the macroscopic model that is spontaneously formed through our senses. This convolution leads to particle models in which particles have macroscopic properties (see points c ,g, above), and
3. the every day science, not scientifically accepted but useful in communication, remains unaffected by the school science experience (see points d, f, above).

Methodological framework.

The sample

Our sample consisted of 70 prospective teachers who systematically attended all the sessions of the programme. Prospective teachers have had experiences about teaching and learning in science since they were students in secondary education and have shaped ideas about both science and science teaching and learning. The majority of them consider science as "difficult" and have massive experiences from their school days when their answers were marked "Incorrect". In addition, traditional teaching has guided them in forming a picture of science as "complicated, exact, irrefutable" and for scientists as persons having a "specific talent". So, the problem of training them how to teach science has three elements: prospective teachers' low level of scientific knowledge, the traditional aspect about science (being exact and irrefutable), and the equally traditional aspect of learning as a process for acquiring the "Correct" answers, usually through memorisation.

The construction of questionnaires (Pre and Post Tests)

Using the constructivist approach we decided to confront prospective teachers with pupils ideas as they are expressed when pupils answer questions about the properties of matter or the changes of state. Prospective teachers were asked to act as "real teachers" and evaluate pupils' answers. Additionally they were asked to discuss their conclusions, to search for possible obstacles in the learning of the topic and finally to propose appropriate teaching interventions, e.g. hands on activities, questions, demonstrations, etc. In order to accomplish our intention we took the following steps:

a) First, after teaching the relevant topics, we collected children's ideas about phenomena related to the particulate nature of matter in primary education. The most common of these ideas with the relative questions were used as source material for Pre-test, Post-test and material for activities in the teaching sessions.
b) Second, we planned a four-session sequence according to the pattern proposed by Driver and Oldham (1986).
c) Third, we designed the analysis procedure.

Prospective teachers questionnaires (Pre Test)

The prospective teachers were given papers filled in by pupils concerning the particulate nature of matter. The paper given to pupils is presented in appendix 1. Subsequently prospective teachers were asked to act as "real teachers" and evaluate pupils' answers. Each answer was to be classified in only one category. The code of the evaluation was as follow:

1) If an answer, according to prospective teachers' opinion was correct it was classified in the category "Correct". Example: "The fizzy drink contains a gas which escapes. The gas has little weight and the total weight will be less".
2) If an answer was evaluated incorrect it was included in the category "Incorrect". Example: "The weight of fizzy drink increases. The light air goes away".
3) If the answer included elements that are correct and others that are incorrect, it was put in the category "Partially correct". Example: "The weight of fizzy drink remains the same. The escaping air doesn't weigh much".
4) If the answer was a version of every day experience that is 'It always happens in the same way' it was put in the category "Tautology". Example: "The fizzy drinks always emit light bubbles. It stops after a while". Or: "The fizzy drink is made in such a way to act like this".
5) If prospective teachers could not put an answer in the above described categories or the answer itself could not be treated as an answer from someone who have been taught physics, a fifth category entitled "Irrelevant answers" existed. Example: "The bubbles go away. The fizzy drink becomes more light for our stomach".

The terminology used for the categorisation of pupils answers is the same with that used for evaluation in every day school practice. Therefore, prospective teachers did not have difficulties in understanding the instructions. In addition it helped it appear more believable that they were going to act as "real" teachers

The Post Tests

For the construction of the Post-test the same material as for the Pre-test was used. Between the two tests there are similarities and differences.

<u>Similarities:</u> The categories in which pupils' answers should be classified are identical. The phenomena about which pupils' ideas were elicited were the same. Moreover the number of answers that prospective teachers had to classify are the same. Again each answer is to be classified only in one category.

<u>Differences:</u> The questions which were addressed to pupils were rephrased or changed. (see appendixes 2,3). Also pupils' answers with different wording and phrasing but reflecting the same misconception as in the Pre-test were used. Some answers were substituted by others with the same meaning.

For the validation of our tests, a group of experienced primary teachers with a degree in physics or chemistry were asked to do the same work done by the prospective teachers. The answers of the prospective teachers were evaluated according to the experienced teachers classification.

Data collection : the four sessions

The prospective teachers worked in small groups (3-4) in classes of about 15-22 persons. The project lasted four weeks and each class had a session per week. The Pre Test was given to them in the first session and the last page (with the results of categorisation) was collected. The other pages of the Pre-test were kept by the prospective teachers and used as the first task in the first session. During the next sessions of the project the prospective teachers used this material in discussions, in devising experimental activities or in proposing teaching interventions. The activities, the aims and the presuppositions were organised as follow:

Session 1

Working hypotheses

The research team began with the following working hypotheses:

Prospective teachers have alternative concepts similar to those of children.

Assessment is one of the teachers' main activities.

Prospective teachers as children had a lot of experiences where they were obliged to answer teachers' questions and accept their criticism. The dichotomy of "Correct" and Incorrect" is a major organiser of their knowledge and their attitudes towards the pupils knowledge.

Activities in the classroom.

The prospective teachers:

worked on children's answers classifying them

worked in small groups comparing between themselves their opinions on answers treated as "Correct".

Fully discussed as a group and decided what the "Correct" answers should be.

Aims

The aims of the research team for this session were:

To provoke disagreement among the prospective teachers in order to ignite the disequilibrium of their ideas.

To ensure that the attainment of the scientific model is easier and more conscious, when the major alternatives are supported and debated.

Session 2

Presuppositions

Prospective teachers have been maltreated as pupils when they did not know the "Correct" answers.

To their disappointment their efforts (transient models in constructivism) used to be evaluated "Incorrect" by their teachers.

Their beliefs from everyday experiences were not discussed in the classrooms creating a dichotomy between the school science and everyday life.

Activities

Prospective teachers:

worked in small groups discussing the "Incorrect", the "Partially "Correct", the "Tautology" and the "Irrelevant" answers

fully discussed their opinions

proposed explanations about the origin and the meaning of these categories.

Aims

To facilitate prospective teachers' use of new particle models and ideas about the elaborated phenomena in the new activities.

To provoke disagreement among them about the "Incorrect" and "Partially Correct" answers that thaws the frozen conceptions behind these categories promoting the constructivist approach about learning.

To extract their explanations concerning the possible sources of the tautology and the irrelevant answers (ideas) that pupils had offered.

c. Sessions 3 and 4

Presuppositions

Prospective teachers have a better particle model that can be used in explaining or predicting phenomena.

The prediction-observation-explanation process can help them to test their ideas.

They lack opportunities for practical laboratory work.

Activities

Prospective teachers:

propose learning activities that could promote successful conceptual change in the classroom

carry out experiments implementing their new ideas about the particulate nature of matter.

write scenarios in which the proposed experiments could function

propose activities addressed to manage the tautology ideas

devise activities referring to the "irrelevant answers" problem

comment the possible results of their proposals.

<u>Aims</u>

To consolidate prospective teachers' new ideas through practical work.
To increase their confidence in planning and doing experiments.
To encourage them in innovating a solid scientific and instructional background.

Results: Analysis and interpretation

The paired Test comparison (Wilcoxon Matched Pairs) was used for the analysis of our results. Each prospective teacher wrote a code-number on his/her answer sheet which was the same for both Pre and Post tests. Thus, their answers were organised in pairs (Pre and Post) in order to study the changes that had happened. Two weeks after the fourth session (six weeks from the Pre-test) prospective teachers started taking the Post-test. This stage lasted two weeks, as they came in small groups on different days. From each answer sheet the sum of "Correct", "Incorrect", etc. answers was calculated. Thus, for each one and for both the Pre and Post Test we summed up the number of pupils' answers that he/she had classified in each category. For example a prospective teacher in the Pre Test treated : 11 answers as "Correct", 15 as "Incorrect", 9 as "Partially correct", 4 as "Tautology" and 5 as "Irrelevant". The same person in the Post Test treated: 3 answers as "Correct", 9 as "Incorrect", 21 as "Partially incorrect", 3 as "Tautology" and 6 as "Irrelevant". The comparison among the sums for each category (for the Pre and Post Test) describes the changes of prospective teachers' ideas not only for the "Correct" the "Incorrect", etc., but also for the scientific knowledge mentioned in the questions. In addition the mobility of prospective teachers' ideas (increase, decrease, stability of numbers that denote how many answers treated as "Correct", "Incorrect", etc.) depicts the influence of teaching intervention. The results for each category are presented and analysed as follows:

Category "Correct"

Our analysis shows that prospective teachers revised their ideas about the scientifically correct explanations, initially given by pupils, and moved closer to the number proposed by the validation group. The validation group decided that according to the school textbooks only three (3) pupils' answers should be put in the category "Correct". In the Pre Test the Mean value of pupils' answers treated as "Correct" was 7,3 and the Std. Dev. was 1,78. In the Post Test the Mean value was 3,8 and the Std. Dev. was 1,4. The decrease in the Std. Dev. values shows that prospective teachers are more confident about their scientific knowledge. The Wilcoxon Matched-Pairs Signed-Ranks Test shows that 93% of prospective teachers decreased the number of pupils' answers that they treated as "Correct", 4% of them increased and only 3% kept the same number. This result is statistically significant (Z= - 6,96 and 2-Tailed P= 0,000).

During the teaching sessions it was revealed that prospective teachers attribute to particles macroscopic properties such as hardness or that molecules expand, evaporate, etc. Many such answers were put in the category of "Correct". At the same time ideas that show a transition to the scientific model were treated as "Incorrect" due to lack of scientific wording. e.g. omission of terms like evaporation, solvent, cohesive etc. For example an answer which depicts that the pupil treats dissolving as a splitting process was classified "Incorrect" while an answer claiming that the molecules are dissolved was classified as "Correct". (See answers 6 and 7 in appendix 2) Another characteristic of prospective teachers that was revealed during the sessions, was that because they felt insecure about their knowledge or they had difficulties in understanding the topic they became "lenient" and accepted as "Correct" answers which, according to their opinion were replies to difficult questions.

Category "Incorrect"

The changes that occurred in this category show that prospective teachers reconsidered their ideas about what should be treated "Incorrect". Specifically, 43% of them decreased the number of answers which initially they had classified as "Incorrect", 43% of them increased, and 4% kept the same number. Reconsideration in our programme might have come from three different pathways: a) by using the scientifically accepted model, b) by recognising specific obstacles in pupils' learning, and/or c) by accepting the constructivist point of view. The statistical results show a slight increase in the Mean value of the number of answers treated as "Incorrect" from 14,4 in the Pre Test to 15,7 in the Post. The Std. Dev. shows an increase form 4,3 to 5,4 pointing to the increase of cautiousness about what should be evaluated as "Incorrect" in teaching pupils.

The debates that arose during the sessions and the search for possible pupils' obstacles in changing their ideas helped prospective teachers in two ways: a) in finding their own obstacles that had led them in treating the topic as difficult, b) in recognising the teachers' responsibility in helping pupils overcome their obstacles, instead of treating pupils' efforts as unsuccessful and their answers as mere "Incorrect". Among the possible obstacles, in learning the particulate nature of matter, the contradiction between the properties of molecules and the properties of the substance they constitute, was considered as the major one.

Category "Partially Correct"

The analysis of the results in this category shows substantial changes in prospective teachers' ideas about the meaning of this traditional term and the origin of the relevant answers. Sixty five percent of the sample increased the number of pupils answers which initially they had put in this category, 25% decreased and only 10% kept the same number. The Wilcoxon Matched-Pairs Signed-Ranks Test shows that the changes are statistically significant (Z= -4 and 2-Tailed P= 0,0001). This is also depicted in the increase of the Mean value from 11,3 in the Pre Test to 14,3 in the Post. The comparison between the decrease in the category "Correct" (3,5 units) and the increase in this category (3 units) points out that the majority of the answers which were subtracted from the first category were added to the "Partially Correct" one. In addition the increase in the Std. Dev. from 3,1 to 5,16 between the two Tests shows strengthening of cautiousness about pupils' difficulties in acquiring scientific knowledge.

Categories "Tautology" and "Irrelevant"

The material (pupils' answers) on which the tests were based resulted in including answers which express either the lack of curiosity (Tautology) or every day sayings about the matter and its transformations (Irrelevant). The maximum number of pupils' answers that could be classified in both categories were estimated by the validation group as follow: In the category "Tautology" they put 6 answers and in the "Irrelevant" 4 answers. Prospective teachers easily recognised these answers and classified them in a similar way. During the sessions they supported their choices claiming for the "Tautology" that: "Pupils describe what always happen in nature. Pupils report the truth of their senses. It is like mentioning a law of nature". Or "..children do not believe in teachers' explanations about the phenomena". Also, they said that they themselves feel more certain working at the macroscopic level describing, predicting, or explaining the phenomena. Although the above claims describe a part of educational reality, they reveal the failure of traditional teaching to successfully use pupils' curiosity and prior knowledge. In addition, pupils' or prospective teachers' reluctance to change their ideas is confirmed within the literature of conceptual change.

The results for the Pre Test and for the category "Tautology" are as follow: Mean value=6,5. Std. 2,3. For the Post Test: Mean value=4 Std.dev=2,5. The decrease in both Mean values shows that prospective teachers became more able to discriminate the meaning of tautology on pupils answers. The paired comparison of prospective teachers categorising results shows that 43% of prospective teachers increased the number of answers they treat as "Tautology", while 48% decreased this number leading to decrease of the Mean value.

During the second session it was proved that the category «Irrelevant» was used by prospective teachers in two different ways: a) to characterise an answer that according to their opinion should not be put in the others, and b) as a "trash" category where «meaningless» answers should be placed. The latter aspect shows that, although prospective teachers did not know the appropriate answer they could recognise the "essence" of a "naive science". The other aspect was supported by claims such as: "That's pupils' foolishness" or "What is the usefulness of taking care of such answers ?" or "These pupils had not studied or the teacher had not given the required effort". These opinions were vigorously debated by prospective teachers who initially were "lenient" and who later on used arguments taken from constructivism. The outcome of this process could not be depicted in the results of the Post Test as it included the same number and peculiarity of pupils' answers. The Mean values for both Pre and Post Test are 3,9 and 4,3 viz. very close to the number 4 which was proposed by the validation group. The lengthy debates proved beneficial for prospective teachers as the 51% of them increased the number of «Irrelevant» answers and 39% decreased them leading to clarification of this traditional term.

Conclusions and limitations.

The results show that prospective primary school teachers when confronted with children's ideas about the particulate nature of matter, initially tend to: a) lack the scientific knowledge about the topic, b) be "strict" or "lenient" according to the "difficulty of the topic" or their attitude to encourage pupils' efforts. We argue that teachers with such characteristics could: a) reinforce pupils' misconceptions or reject pupils' efforts, b) lack a theoretical framework within which they could analyse pupils' difficulties and search for teaching strategies.

The Post Test results show improvement in terms of scientific knowledge which is coupled with increasing awareness about the criteria (i.e. school science) on which the characterisation "corect" and "incorrect" is based.

The number of questions and the peculiarity of answers in children's protocols affected the tests and their function in the evaluation of the intervention, although they describe the educational reality in primary education. Choices such as the limited number of categories in Pre and Post tests, the number of the sample, and the questions given to children are parameters which should be tested through research in future research activities.

References

ANDERSSON, B. (1992) Pupils' conceptions of matter and its transformations (age 12-16) In: P.L. Lijnse, P. Licht, W de Vos, A.J. Waarlo (Eds) *Relating Macroscopic Phenomena to Microscopic Particles. A central problem in secondary science education.* University of Utrecht . Netherlands

BROOK, A., BRIGGS, H. and DRIVER, R. (1984) Aspects of secondary students understanding of particulate nature of matter. Leeds : Children's Learning In Science project. Center for Studies in Science and Mathematics Education. University of Leeds.

DREYFUS, A., JUNGWIRTH, E. and ELIOVITCH, R. (1990) Applying the "Congnitive Conflict" Strategy for Conceptual Change - Some Implications, Difficulties, and Problems. *Science Education 74(5)* 555- 569

DRIVER, R. and OLDHAM, V. (1986) A constructivist Approach to Curriculum Development in Science. *Studies in Science Education, No 13* 105-122

DUIT, R. (1994) Conceptual change approaches in science education Paper presented at the Symposium on Conceptual change. Jena Germany 1994

HEWSON, P.W. and HEWSON , M. G. (1987) Science Teachers' Conceptions of Teaching: Implications for Teacher Education. *International Journal of Science Education. 9 (4)* 425-440

JOHNSTONE, K. (1992) Students' responses to an active learning approach to teaching the particulate nature of matter. In: P.L. Lijnse, P. Licht, W de Vos, A.J. Waarlo (Eds) *Relating Macroscopic Phenomena to Microscopic Particles. A central problem in secondary science education*. University of Utrecht. Netherlands

KOKKOTAS, P. and HATZINIKITA, V. (1994) The concept of the molecule in fourth year primary education students of the University of Athens. In: Proceedings of ATTI and European Conference on Research in Chemical Education. September 1993 University of Pisa. Italy

KOKKOTAS, P. et all. (1994) *The* Language of Physics. A Case Study of the Concept of Force in Primary Education. Paper Presented in the International Congress in "Thinking Physics for Teaching" Rome. Italy

KOULAIDIS, V. and HATZINIKITA, V. (1996) *Pupils' models of explanation on changes of matter* Proceedings, III ECRICE Conference, University of Lublin.

KRUGER, C. and SUMMERS, M. (1988) Primary School Teachers' Understanding of Science Concepts. *Journal of Education for Teaching, Vol. 14, No.3*

KRUGER, C., SUMMERS, M. (1989) An investigation of some primary teachers' understanding of changes in materials. *SSR, Dec 1989, 71 (255)* 17-27

MILLAR, R. and DRIVER, R. (1987) Beyond Processes. *Studies in Science Education. 14 (1987).* 33-62

NUSSBAUM, J. and NOVIC, S. (1978*)* Junior High School Pupil's Understanding of the Particulate Nature of Matter: An Interview Study *Science Education 62(3): 273-281*

OSBORNE J. (1966) Beyond Constructivism. *Science Education (80) (1)* 53-82

PIAGET, J. and INHELDER, B. (1974) *The child's construction of quantities.* London: Routlege and Kegan Paul

SLONE, M. and BOKHURST, F.D. (1992) Children's understanding of sugar water solutions *International Journal of Science Education 14(2),* 221-235

SOLOMON J. (1994) The rise and the fall of Constructivism *Studies in Science Education 23* 1-19

STAVRIDOU, H., SOLOMONIDOU, C. and PAPADIMITRIOU, V. (1994) Student - Teachers' Conceptions about Physical and Chemical Transformations of Matter. In: Proceedings of ATTI and European Conference on Research in Chemical Education. September 1993 University of Pisa. Italy

Appendix 1 Questions addressed to pupils

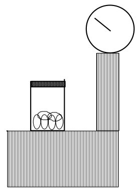
Question 1 When we open a bottle containing a fizzy drink i.e. Coca Cola, Sprite, we observe bubbles coming out. The drink becomes heavier, lighter or its weight does not change? Explain your choice.

Question 2 We can sense the existence of substances like benzine or perfumes form a distance without having any eye contact. How do you explain it ?

Question 3 Substances like ice, chocolate, etc., when heated become liquids. How do you explain it ?

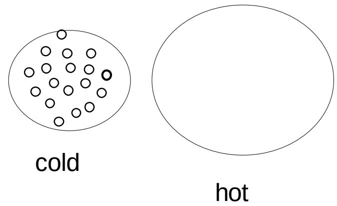
Question 4 Substances like salt, sugar etc., are dissolved when put in water. How do you explain it ?

Question 5 A closed jar containing ice cubes is placed on the scale and the indication is marked. Later the ice-cubes became liquid. Then, the needle points less, more or the same? Explain your choice.



Question 6 Materials like wood resist changing their shape, whereas others like plasticine don't. How can this difference be explained?

Question 7 Imagine that a small balloon contains 18 molecules of air. The balloon is heated and becomes bigger. Draw the molecules in the hot balloon. Explain your drawing.



Appendix 2 Example from the Pre-test.

Pupils in the 6th grade of Primary Education were asked to answer a questionnaire to elicit their ideas about the states of matter and its transformations. Pupils replied to the questionnaire two months after their last relevant lesson. The most common of pupils' answers were collected and assembled along with the question they refer to.
You are asked to act as "real teachers" and evaluate pupils' answers. You can classify pupils' answers in one of the next categories: "Correct", "Incorrect", "Partially correct", "Tautology", "Irrelevant". Each answer should be put in one category only. Write your evaluation in the box next to each answer.

Question 4 Substances like salt, sugar etc. are dissolved when put in water. How do you explain it?

<u>Pupils' answers</u>

1. When sugar is put in water and we stir the water the sugar dissolves.
2. These substances are not hard enough to resist dissolving.
3. The water has the force to dissolve these materials.
4. It's a property of sugar or salt .
5. The water absorbs the molecules of sugar or salt .
6. When these materials are put in water they split in many tiny parts that you can' t see.
7. The molecules of the substances are dissolved in the water .
8. The sugar or the salt became liquid sugar or liquid salt.

Appendix 3 Example from the Post Test

In the Post Test the above section of the Pre Test presented as follow:

A few days after teaching the topic of dissolving, a teacher asked his/her pupils to explain the phenomenon. Pupils' answers are:
Pupils' answers

1. Some amount of these substances melt and become like liquid. This liquid is mixed with the water .

2. The sugar or the salt are made from a huge number of small particles that are spread in the water. You can't see them but you can taste them.

3. Sugar is dissolved by stirring. Unless you stir the sugar it stays at the bottom .

4. Weak granules like sugar or salt can't resist splitting into small particles .

5. Water has something special that can dissolve materials like salt, sugar, soap powder, etc.

6. Materials like sugar or salt are made up in such a way to be dissolved in some liquids like water. Sugar does the same in milk.

7. The water becomes sweet or salty because it absorbs many small molecules.

8. The materials are formed from molecules. When they are put into water these molecules are dissolved and the water becomes salty or sweet.

You are asked to act as «real teachers» and evaluate pupils' answers. You can classify pupils' answers in one of the next categories: "Correct", "Incorrect", "Partially correct", "Tautology", "Irrelevant". Each answer should be put in one category only. Write your evaluation in the box next to each answer.