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PRIMARY SCHOOL TEACHERS' VIEWS ON FUNDAMENTAL CHEMICAL CONCEPTS

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ABSTRACT: An attempt is made to examine primary school teachers' views on the composition and classification of matter. The sample was constituted of 75 teachers who work in primary schools of Thrace, Greece. Teachers were asked: a) through an open ended questionnaire to define some of the major concepts of chemistry and to correspond these concepts to specific examples; b) to draw concept maps. The concepts under study were: matter, pure substance, compound, element, mixture, solution, molecule and atom. According to the findings: a) teachers seem to be familiar with those concepts which are extensively presented in the textbooks; b) they misunderstand some concepts since they are not familiar with the language of chemistry and their thinking is being influenced by the everyday use of some terms; c) some of the concepts under study can be perceived sensory; d) some concepts are perceived in a limited way. The limited knowledge of some concepts becomes evident from the fact that teachers often fail to draw relationships between concepts. In addition, the majority of the concepts under study cannot be defined easily by the teachers and can be described only through the use of examples, whereas concepts such as molecule and atom are described with difficulty even through the use of examples. Results are further discussed with respect to their implications. [*Chem. Educ. Res. Pract. Eur.*: 2000, 1, 237-247]

KEYWORDS: chemical concepts; matter; substance; compound; element; mixture; solution; molecule; atom; primary teachers' views; concept maps

INTRODUCTION

Teachers' views on science related concepts have been studied quite extensively in the last thirty years. According to these studies, teachers seem to hold «inadequate conceptions» of science (Hodson, 1993) or have ideas which are not scientifically accepted. Many of these ideas are similar to those held by children (Kruger & Summers, 1988; Kokkotas & Hatzinikita, 1994). Teachers' views on chemistry have been studied to a lesser degree, in comparison to those of students, and mostly in relation: (a) to the difficulties teachers are faced with in chemistry classrooms (Costa, 1997; De Jong, Acampo, & Verdonk, 1995); and (b) to what students and teachers may consider as difficult topics in secondary school chemistry curriculum (Lehman, 1989; McRobbie & Tobin, 1995). Only a few studies focus on teachers' misconceptions (Kruger & Summers, 1988; Kokkotas & Hatzinikita, 1994; Ahtee & Asunta, 1995).

Moreover, it has been demonstrated that teachers' thinking affects their classroom behaviour. On one hand, it has been shown that teachers' views of the discipline influence the

ways they teach and limits the kinds of science activities that children do in classrooms or laboratories (Costa, 1997; Abell & Smith, 1994). On the other hand, teachers who have well-developed subject matter structures are more efficient at presenting subject matter to students (Nott & Wellington, 1996; Gess-Newsome & Lederman, 1995). Finally, teachers' misconceptions even influence children's understanding of science related concepts (Nott & Wellington, 1996; Gess-Newsome & Lederman, 1995; Johnson, 1998) or more specifically of chemistry related concepts (De Jong, Acampo, & Verdonk, 1995; Lehman, 1989; McRobbie & Tobin, 1995).

Within this context and given the fact that research concerning teachers' views on chemistry is rather limited in Greece (Kokkotas & Hatzinikita, 1994; Tsaparlis, 1998; Kokkotas, Vlachos, & Koulaidis, 1998), in this study, an attempt is made to examine primary school teachers' views on the composition and classification of matter.

We are especially interested in the views held by elementary school teachers, since past studies have been dominated by the examination of secondary science teacher views and furthermore, elementary school teachers are the ones who offer young children their first school experiences with science in general or chemistry in particular. Moreover, the study of in-service teachers' misconceptions becomes of great importance since primary teachers' in Greece in the near past had a limited formal education on chemistry whereas the new programs of training which have been developed for either pre-service or in-service teachers during the last few years have not provoked teachers' interest.

METHODOLOGY

The present study aimed at investigating teachers' understanding of some of the fundamental chemistry concepts. More specifically, the concepts under study were *matter*, *pure substance*, *compound*, *element*, *mixture*, *solution*, *molecule* and *atom*. The sample was constituted of 75 teachers (37 male and 38 female) who have been working in primary schools in the area of Thrace, Greece. The time teachers have been working in schools ranged from 5 to 20 years. The study took place during a teacher in-service training course.

Data were selected through:

- *an open ended questionnaire* especially constructed for the purposes of the present study. Teachers were asked to give definitions of the above concepts and also to correspond those to a list of examples.
- *the construction of a concept map* aiming at an in depth exploration of the teachers' subject matter knowledge through the relationships expressed among the various concepts. Teachers were asked to draw maps linking the concepts to each other and the resulting maps formed part of the data.

The main procedure (i.e. the completion of the questionnaire and the construction of the concept maps) lasted 60 minutes. Beforehand, a series of examples were presented to teachers for about 20 minutes in order for them to become familiar with the construction of concept maps.

Data from the open ended questionnaire were classified according to a category scheme especially developed for the present study by two independent ratters (Oppenheim, 1976). Data from the concept maps were qualitatively analysed in relation to the questionnaire categories by the first author and an independent coder. Moreover, since the

above chemistry concepts are discussed in the fifth and sixth grade primary school textbooks, teachers' answers were further compared to the descriptions given in these textbooks.

RESULTS AND DISCUSSION

Data from the open ended questionnaires are presented in Tables 1-8¹. Table 9 includes the findings concerning the correspondence between the concepts under study and the given examples. Data from concept maps are also presented in the discussion which follows.

Matter

As Table 1 shows, only 9% of the teachers defined *matter* as «*anything that occupies space and / or has mass*», thus approaching the concept in a more scientifically acceptable way. Moreover, a significant number of teachers give definitions of matter which are similar to those presented in the textbooks or are based on experience or sensory perception. Thus, 27% of the teachers defined matter as «*anything which is around us*» or «*anything we can sense*». The latter definition is based solely on sensory perception (Lee *et al.*, 1993; Stavy, 1990), and was given by 11% of the teachers. Moreover, an equivalent percentage (27%) of the teachers defined matter as «*anything which could be met in three states: solid, liquid or gas*», thus discussing the concept at an empirical level.

TABLE 1. Teachers' definitions of matter.

Teachers' definitions	N	% of teachers
Anything that is around us and/or we can sense	20*	27
Anything that can be solid, liquid or gas	20*	27
Anything that exists and/or something that everything consists of	18	24
Anything that occupies space and/or has mass	7	9
Anything that consists of molecules	7	9
Miscellaneous	4	5
I don't know/No answer	8	11

* Nine (9) of the teachers responded in both categories.

Apart from those answers which fell within the first category «*anything that is around us/ anything that we can sense*» an additional 24% of the teachers' answers fell into the third category «*anything that exists*». What might be the consequences of such a general conception of matter? As Lee *et al.* (1993) report, at least for children, such a general consideration of matter could probably lead to difficulties in making the distinction between matter and energy.

With respect to the data concerning the correspondence of the given examples to the concept of matter (Table 9), the percentage of teachers who responded correctly are low. Is it difficult for teachers to correspond the specific examples to this concept or is the correspondence self evident for them? The answer to this question is an issue for further

¹ Teachers' responses fell into one category for all concepts, except that of matter where responses fell into two categories. Consequently, the calculation of frequencies was based on the number of respondents in all cases, except the case of the definition of matter where frequencies were based on the total number of responses.

investigation, although, according to some teachers' reports, in informal discussions following the completion of the questionnaire, the latter seems to be more possible. Despite this fact, however, it seems that teachers' answers follow a specific pattern: the majority of teachers consider soil as matter (60%), but only very few consider oxygen or filtered air as such (15% and 17%, respectively).

Pure substance

Pure substance (Table 2) has mostly been understood as «*the substance without admixtures*» (57%). It seems therefore, that not only students (Johnson, 1996), but teachers as well give an everyday meaning to the term «pure». As Table 2 also shows, the concept of *pure substance* is rarely related (20% of the teachers) with those of *compound* and/or *element*. This fact is also shown more clearly by the data deriving from concept maps: According to drawings, 17% of the teachers gave these relationships in a correct way, while 9% of the teachers believe that pure substance is the same as compound (Figure 1). According to the data concerning the correspondence of the given examples to the concept of pure substance (Table 9), distilled water is considered to be a pure substance by 65% of the participants, whereas gold or oxygen are considered as such only by 20% and 11% of the sample respectively.

TABLE 2. Teachers' definitions of pure substance.

Teachers' definitions	N	% of teachers
Any substance without admixtures	43	57
Compound and/or element	15	20
Miscellaneous	10	13
I don't know/No answer	7	9

Compound and element

Compound seems to be a quite familiar concept and the majority of teachers' definitions (59%) are similar to those presented in the textbooks. Most of them (21 teachers) defined a compound as «*the substance which is composed of elements in specific proportions and has different properties from those of its constituent elements*» whereas the rest (9 teachers) added that this substance «*cannot be easily separated in anything simpler*». In addition, 19% of the teachers claimed that a compound is «*something that results when elements are combined under specific proportions*».

At this point it should be noted that, according to the open ended questionnaire results, the majority of teachers (88%) reported that a compound consists of elements (Table 3). However, 29% of the teachers seem to overcome the fact that elements exist in other forms of matter as well, and report that «*anything which consists of elements is a compound*». Similar results are deriving from the concept maps as well: the majority of teachers (71%) indicated through their maps that a compound consists of elements, whereas 33% of them drew maps where it was shown that anything which consists of elements is a compound. Finally, as Table 9 shows, teachers consider distilled water (75%) and sugar (81%) to be compounds whereas some believe that air is a compound as well (15%).

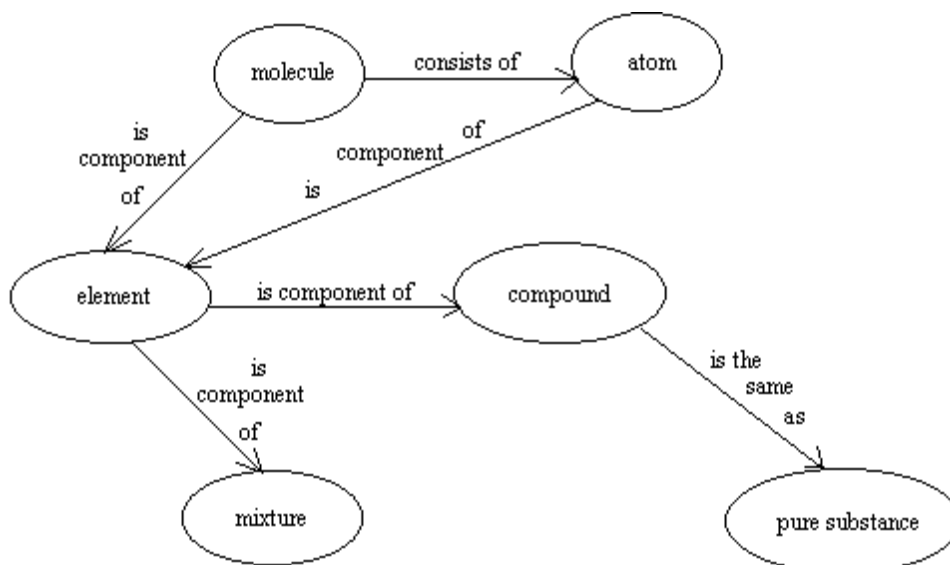


FIGURE 1. An example of a teacher-produced concept map.

TABLE 3. Teachers' definitions of compound.

Teachers' definitions	N	% of teachers
The substance which is composed of elements in specific proportions and has different properties from those of its consisting elements (and cannot be easily separated in anything simpler)	30	40
Anything which consists of elements	22	29
Something that results from a combination of elements under specific proportions	14	19
Miscellaneous	9	12
I don't know/No answer	0	0

With respect to the concept of *element*, as Table 4 shows, a high percentage of teachers (47%) gave a variety of definitions which cannot be put in specific categories. Some of these definitions did not have any meaning whereas others showed that elements are confused with atoms (i.e. «*element is called the atom having a specific number of protons*»). A similar consideration of element has been reported by Schmidt (1998) who, discussing about the periodic table, points out that the term *element* is often used as a synonym for *atom of an element*.

The concept of element, therefore, seems to be an abstract concept which is difficult to be defined. According to our study, only 17% of the respondents define correctly an element as «*the most simple form of matter*», whereas 15% of them reported that an element is «*something that can be found in nature and has specific properties*».

Although an element was difficult to be defined, it was easy to be described through examples. Table 9 shows that it is very clear to the teachers that oxygen (96%) and gold (97%) are indeed elements.

TABLE 4. *Teachers' definitions of element.*

Teachers' definitions	N	% of teachers
The most simple form of matter	13	17
Something that can be found in nature and has specific properties	11	15
Miscellaneous	35	47
I don't know/No answer	16	21

Finally, data from concept maps show that the majority of teachers (71%) consider elements as components of compounds, whereas only few are able to relate elements to mixtures (37%), solutions (27%) and pure substances (11%). Teachers, thus, seem to believe that: the concepts element and compound are strongly related to each other, the concepts element and mixture are related less, whereas the concepts element and solution or element and pure substance are related even less.

Mixture and solution

Mixture seems to be a well understood concept. Table 5 shows that a total of 63 teachers (84%) are aware of information which is extensively presented in the textbooks such as that no specific proportion of constituents is needed for the preparation of a mixture or that the constituents of a mixture conserve their properties. Moreover, 12 of these teachers added that a mixture can be easily separated in its constituents.

Results further suggest that it is difficult for teachers, as it is for students (Lee et al, 1993), to use the language of chemistry: teachers' definitions of mixture are not very clear, whereas there seems to be a confusion concerning the concepts of mixture and compound. The verbs «mix» and «combine» are, also, used as synonyms.

Concept maps show that teachers consider elements (39%), compounds (24%) or pure substances (29%) as constituents of mixtures. Moreover, Table 9 shows that the majority of teachers consider soil (79%) and air (75%) as mixtures.

TABLE 5. *Teachers' definitions of mixture.*

Teachers' definitions	N	% of teachers
Something that results by mixing/combining substances in random proportions and its constituents conserve their properties (and can be easily separated in its constituents)	63	84
Miscellaneous	12	16
I don't know/No answer	0	0

Solution appears to be a concept which is perceived in a limited way. Table 6 shows that 54 teachers (72%) believe that solutions are in liquid state. The majority of them (36 teachers) defined solution using the verb «dissolve» whereas 18 teachers used the verb «combine». The difficulty, therefore, to use the language of chemistry is present again. Moreover, many of the teachers meant or clearly reported that a substance in order to be dissolved should be in solid state. The concept of solution, thus, is mainly perceived as the

TABLE 6. *Teachers' definitions of solution.*

Teachers' definitions	N	% of teachers
Something that results by dissolving substances into a liquid	36	48
Something that results by combining substances with a liquid	18	24
Miscellaneous	15	20
I don't know/No answer	6	8

solution of a solid in a liquid. Within this framework, teachers believe (Table 9) that sugar in water is a solution (84%) while filtered air is not (0%).

With respect to concept mapping, only 5% of the sample indicated that solution is a case of mixture. Similarly, Table 9 shows that only 16% of the teachers indicated that sugar in water is a case of mixture as well. Moreover, concept maps suggest that teachers consider elements (27%), compounds (11%) or pure substances (23%) as constituents of solutions.

Molecule and atom

Both *molecule* and *atom* are in general considered by teachers as the smallest part of matter. Table 7 shows that the majority of teachers (77%) give for the molecule similar definitions to those offered by the textbooks which, however, cannot be considered as correct: «*Molecule is the smallest part of matter, which conserves the properties of the corresponding matter*». On the other hand, the atom is mostly (36% of the teachers), defined as a component of the molecule (Table 8), whereas 8% (Table 7) of the teachers used the same relation (the molecule consists of atoms) to define the concept of molecule. Similar results derive from concept maps, where 61% of the teachers drew that «*the molecule consists of atoms*».

Comparing the results of Tables 7 and 8, it seems that teachers have not a clear view of the concepts molecule and atom. Some teachers give exactly the same definition for either concept: as Table 7 shows, 12% of the teachers defined molecule as «*the smallest part of matter that exists*» whereas 28% claimed exactly the same for the atom (Table 8). Other teachers consider both concepts as opposites, in the sense that the molecule (Table 7) is «*the smallest part of matter, which conserves the properties of the corresponding matter*» (77% of the teachers) whereas an atom (Table 8) is «*the smallest part of matter, which does not conserve the properties of the corresponding matter*» (19% of the teachers).

In concept maps, molecules and atoms are recognized as components of elements (36%), compounds (13%), mixtures (4%) or solutions (4%).

TABLE 7. *Teachers' definitions of molecule.*

Teachers' definitions	N	% of teachers
The smallest part of matter which conserves the properties of the corresponding matter	58	77
The smallest part of matter that exists	9	12
The smallest part of matter which consists of atoms	6	8
Miscellaneous	2	3
I don't know/No answer	0	0

TABLE 8. *Teachers' definitions of atom.*

Teachers' definitions	N	% of teachers
The component of the molecule	27	36
The smallest part of matter that exists	21	28
The smallest part of matter which does not conserve the properties of the corresponding matter	14	19
Miscellaneous	8	11
I don't know/No answer	5	7

TABLE 9. *Correspondence of the concepts to specific example.*

Concepts / Examples	Matter		Pure substance		Mixture		Solution		Chemical compound		Chemical element	
	N	%	N	%	N	%	N	%	N	%	N	%
Gold	21	28	15	20	0	0	0	0	0	0	73	97
Distilled water	28	37	49	65	0	0	2	3	56	75	0	0
Soil	45	60	0	0	59	79	0	0	1	1	1	1
Oxygen	11	15	8	11	0	0	0	0	0	0	72	96
Sugar	25	33	16	21	1	1	0	0	61	81	0	0
Sugar in water	21	28	1	1	12	16	63	84	5	7	0	0
Filtered air	17	23	4	5	56	75	0	0	11	15	1	1

CONCLUSIONS AND IMPLICATIONS

The analysis of the data of the present study, have revealed some interesting features of primary teachers' views on some of the fundamental chemistry concepts.

Teachers seem to be familiar with those concepts which are extensively presented in the textbooks. Their definitions of the concepts mixture and compound, for example, are more

elaborated and very similar to those of the textbooks. It seems, therefore, that teachers do not rely only on the content knowledge they acquired during their training as relevant studies

suggest (Abell & Smith, 1994; Gess-Newsome & Lederman, 1995). The content knowledge of the teachers of our study can be credited on the textbooks they are currently using as well.

Textbooks, however, may produce or reinforce misconceptions. According to our findings, in some cases, teachers' definitions are related to unclear information presented in the textbooks. These results are in accordance to those studies examining pupils' misconceptions. As Johnson (1988) reports, examples of misleading diagrams and phrases found in textbooks seem to be related to the mistakes pupils make when they are talking about the particle theory.

As research evidence suggests, teachers' conceptions are also influenced by everyday science and language (Abell & Smith, 1994; Schmidt, 1998). In the present study, teachers misunderstand some concepts since they are not familiar with the language of chemistry (i.e. the verbs «mix» and «combine» are mostly used as synonyms), whereas their thinking is being influenced by the everyday use of some terms (i.e. pure substance has mostly been understood as «*the substance without admixtures*»).

Moreover, some concepts are perceived in a limited way. The majority of teachers believe, for example, that solutions are in liquid state. Taking, also, into consideration the fact that teachers' responses fell into single categories in all cases but that of *matter*, we might say that teachers' definitions discuss only one facet of the concepts under study. In accordance with other studies (De Jong, Acampo, & Verdonk, 1995; Abell & Smith, 1994), teachers, therefore, seem to have a limited understanding of these concepts, whereas their views seem to be narrowly focused.

The limited knowledge of some concepts is further shown from the fact that teachers often fail to draw relationships between concepts. (i.e. although most teachers consider elements as components of compounds, only few are able to relate elements to mixtures, solutions and pure substances). In addition, the majority of the concepts under study cannot be defined easily by the teachers and can be described only through the use of examples, whereas concepts such as molecule and atom are described with difficulty even through the use of examples.

Finally, in accordance with studies concerning children's alternative conceptions (Lee *et al.*, 1993; Stavy, 1990), a significant percentage of the teachers of the present study give definitions which are based on sensory perception. Matter, for example, has been defined as «anything that we can sense». It seems therefore, that these teachers hold a simplistic view of matter which is similar to that of children. As Lee *et al.* (1993) argue, discussing about sixth grade pupils' conceptions of matter and molecules, these intuitive definitions do not help at least the pupils to distinguish reliably between examples of matter and examples of non-matter. Further research is needed therefore, to examine if the same holds true for teachers as well.

With respect to the implications of the above findings, our data do not allow us to make any specific suggestions about the teaching of these concepts in order to improve teachers' conceptions. However, our findings show that there are at least two major issues which chemistry teacher education programs (in or pre- service) should take into consideration: (a) that teachers' content knowledge is quite limited; and (b) that everyday use of language interferes and further inhibits teachers' understanding. Are teachers aware of these limitations? How do they deal with them in the classroom? Since teaching and learning are interactive processes, to what extent do these misconceptions reinforce the corresponding ones made by children? These are issues for further investigation.

However, to what extent teachers' views on chemistry concepts might reflect their beliefs about learning and teaching? We know from other studies that teachers' views about the nature of science are closely related to similar beliefs (Abell & Smith, 1994). Some

researchers suggest that they have found direct influences of teachers' knowledge of subject matter on classroom practice. Other researchers feel that such interactions are much more complex than initially envisioned, based upon the many factors that appear to interfere with the direct translation of teachers' views to students. These factors include the teaching context (Brickhouse & Bodner, 1992), the curriculum (Lantz & Kass, 1987), and the students themselves (Costa, 1997).

In addition, there is the need for developing more affective (pre- or in service) teacher training programs which will enable teachers to fully understand relevant concepts and develop effective teaching strategies. It is well evidenced that traditional teaching methods of science in general or chemistry in particular are not effective enough in changing prospective teachers' misconceptions. When alternative methods, however, are employed, student teachers' views can be broadened (Nott & Wellington, 1996; Gess-Newsome & Lederman, 1995; Clement, 1982). According to Abell & Smith (1994), science student teachers should be provided with opportunities to reflect on their conceptions, become aware of them and search for alternative ideas. When this is done, there seems to be an enhancement of knowledge. Moreover, teachers need experiences using scientific models to solve problems, examining alternative models and wrestling with the modification of models in light of new evidence. Thus, richer images of science should be provided during their training.

Finally, it is true that, today, prospective teachers in Greece through attending the university departments of primary education, are addressed to more science courses than student teachers in the past. However, further care should be taken by primary education departments to evaluate and improve the existing teacher training programs.

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REFERENCES

- Abell, S. K. & Smith, D. C. (1994). What is science? Preservice elementary teachers' conceptions of the nature of science. *International Journal of Science Education*, 16, 475-487.
- Ahtee, M. & Asunta, T. (1995). Finnish lower secondary pupils' and teacher trainees' ideas on burning. Research in Chemical Education and its influence on teaching chemistry at school. In R. M. Janiuk (Ed.) *Proceedings of the 3rd ECRICE*, pp. 112-116. Lublin-Kazimierz, Poland: Maria Curie-Sklodowska University.
- Brickhouse, N. W. & Bodner, G. M. (1992). The beginning science teacher: Narratives of conceptions and constraints, *Journal of Research in Science Teaching*, 29, 471-485.
- Clement, J. (1982). Students' preconceptions in introductory mechanics. *American Journal of Physics*, 50, 66-71.
- Costa, V. B. (1997). How teacher and students study "all that matters" in high school chemistry. *Journal of Science Education*, 19, 1005-1025.
- De Jong, O., Acampo, J., & Verdonk, A. (1995). Problems in teaching the topic of redox reactions: actions and conceptions of chemistry teachers. *Journal of Research in Science Teaching*, 32, 1097-1110.
- Gess-Newsome, J. & Lederman, N. G. (1995). Biology teachers' perceptions of subject matter structure and its relationship to classroom practice. *Journal of Research in Science Teaching*, 32, 301-325.
- Hodson, D. (1993). Towards a more critical approach to practical work in school science. *Studies in Science Education*, 22, 85-142.
- Johnson, P. (1996). What is a substance. *Education in Chemistry*, 33, 41-45.

Johnson, P. (1998). Progression in children's understanding of a "basic" particle theory: A longitudinal study. *International Journal of Science Education*, 20, 393-412.

Kokkotas, P. & 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*, pp. 241-246. University of Pisa, Italy.

Kokkotas, P., Vlachos, I., & Koulaidis, V. (1998). Teaching the topic of the particulate nature of matter in prospective teachers' training courses. *International Journal of Science Education*, 20, 291-303.

Kruger, C. & Summers, M. (1988). Primary school teachers' understanding of science concepts. *Journal of Education for Teaching*, 14, 13-17.

Lantz, O. & Kass, H. (1987). Chemistry teachers' functional paradigms. *Science Education*, 71, 117-134.

Lee, O., Eichinger, D. C., Anderson, C. W., Berkheimer, G. D. and Blakeslee, T. D. (1993). Changing middle school student's conception of matter and molecules. *Journal of Research in Science Teaching*, 30, 249-270.

Lehman, J. (1989). Chemistry teachers' and chemistry students' perceived advantages and disadvantages of high school chemistry labs. *School Science and Mathematics*, 89, 510-514.

McRobbie, C. & Tobin, K. (1995). Restraints to reform: the congruence of teacher and student actions in a chemistry classroom. *Journal of Research in Science Teaching*, 32, 373-385.

Nott, M. & Wellington, J. (1996). Probing teachers' views of the nature of Science: How should we do it and where should we be looking? In G. Welford, J. Osborne & P. Scott (eds.) *Research in Science Education in Europe*, pp. 283-295. London: Falmer Press.

Oppenheim, A.N. (1976). *Questionnaire Design and Attitude Measurement*. London: Heinemann.

Ruiz-Primo, M. A. & Shavelson, R. J. (1996). Problems and issues in the use of concept maps in science assessment. *Journal of Research in Science Teaching*, 33, 569-600.

Schmidt, H. J. (1998). Does the Periodic Table refer to chemical elements? *School Science Review*, 80 (290), 71-74.

Stavy, R. (1990). Children's conception of changes in the state of matter: From liquid (or solid) to gas. *Journal of Research in Science Teaching*, 27, 247-266.

Tsaparlis, G. (1998). Secondary science teachers' views on nature and the properties of molecules (in Greek). *Ekpaideutikes Prosengiseis gia tis Physikis Epistemes*, No. 2, 20-22.

