Primary teachers' views and descriptions regarding some science activities

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Abstract: The views and the descriptions of 228 primary teachers on the use and the carrying out of some chemistry-related practical activities were studied. The research took place in the context of an in-service training course. As research tool, a questionnaire was used, where tasks dealing with three hands-on activities on chemistry topics, were included. According to the results, teachers had generally both the necessary knowledge to carry out such activities and the ability to describe procedures with the use of appropriate equipment and materials, to a satisfactory degree. However, their responses ranged from a more correct and complete level to a more generally descriptive and incomplete level. Results also suggest that, the gender and the use of science activities in school had an impact on their descriptions. [*Chem. Educ. Res. Pract.,* 2007, **8** (1), 52-60]

Key words: Primary teachers, descriptions, primary science, (hands-on) science activities.

Introduction

Although teaching science is one of the main objectives for a primary teacher, many avoid it – especially chemistry topics. They give higher priority to other subjects (e.g., reading), they often do not have the requisite subject matter knowledge, and they don't feel very comfortable with science (Smith and Neale, 1989; Appleton and Kindt, 1999; Schibeci and Hickey, 2000; Appleton, 2003). This could be also related to the female teachers' predominance in primary education (Johnston et al., 1999), since the female identity is more connected to theoretical sciences (such as humanities, social sciences or art), than to practical sciences (Kelly, 1987; Arnot et al., 1999).

Many of the above preconditions for a successful implementation of hands-on science activities in primary education are lacking, and such activities are not very common in primary schools. Since science activities are very important for primary education, they should be included in the primary teachers' practice, as they can help children to overcome their difficulties in understanding science concepts to a certain degree (Gabel, 1999; Lavonen et al., 2004; Papageorgiou and Tsiropoulou, 2004). So, the question addressed here is this: What are the views and descriptions of the teachers themselves regarding such hands-on science activities in school?

As Appleton (2002) suggests, among the requirements for a hands-on science activity is that the background science content for the activity should be already known to the teacher. In particular, such science activities on chemistry and physics topics need further training support and thorough knowledge and understanding of the science subject matter; accordingly, the teachers requested more practice in activity planning (Asunta, 1997). Additionally, teachers who intend to carry out hands-on activities in school should both be knowledgeable about the relevant topics, and know how to use particular materials and equipment (Kepler, 1998).

In this context, we decided to study the views and the descriptions of primary teachers regarding both their ability (in the sense of the requisite knowledge) to carry out some hands-on science activities on chemistry topics and their use of the appropriate equipment and materials.

Research methods

In this study we attempt to answer the following questions:

- What are the teachers' descriptions regarding both their ability to carry out some hands-on science activities on chemistry topics, and the practical handling of appropriate equipment and materials?
- What are the teachers' views on the use of such science activities in primary schools?
- To what extent teachers' views and descriptions are related to their gender?

In order to answer these questions, 228 teachers of primary education (97 male and 131 female) who have been working in Greek primary schools in the region of East Macedonia and Thrace participated in this study. The time teachers had been working in schools, ranged from 5 to 20 years. The study took place during an in-service teachers' training program. The teachers of the sample who participated in this program were divided into nine classes.

Data were collected using an anonymous questionnaire, especially constructed for the purposes of the present study, which asked teachers to comment on their use of hands-on science activities in school. The three questions of the questionnaire are described in Figure 1., In addition, the teachers were asked to work on three tasks concerning hands-on science activities; the tasks are given in Figure 2. The time for the completion of the questionnaire and the tasks was one hour. The data collected were qualitatively analysed by two of the authors independently, who classified the data according to a category scheme especially devised for the present study. Additionally, in order to compare the teachers' ability to carry out the activities in the three tasks and to determine the effect of the 'gender' on the teachers' descriptions, we coded the data quantitatively. The coding was done by the two authors, who had also analysed the teachers' responses qualitatively.

Figure 1. Description of the questionnaire.

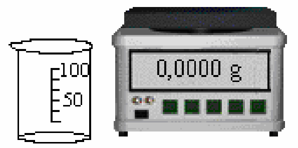
Question 1: In this multiple choice question, teachers were asked to check how often they used hands-on science activities in school (often/sometimes/never)

Question 2: Teachers were asked to give some possible reasons for not using hands-on science activities in school as often as they would have liked, if this was the case. There were some possible reasons suggested (Hands-on science activities are too difficult / There are hazards using such activities / I haven't been trained for that), but they could also give their own reasons.

Question 3: Teachers were asked to give some possible reasons, in case they did not want to use hands-on science activities in school at all. There were also some possible reasons suggested (I don't think that such activities help the learning process / There are hazards using such activities), but they could also provide their own reasons.

Figure 2. The three tasks.

Task 1: It is assumed that a balance and a beaker with volume graduations are available (the relevant equipment is shown below). Teachers are asked to describe the procedure that they would follow in order to determine the density of an unknown liquid. The following reminder is also given: the density of a liquid can be calculated by dividing the mass by the volume.



Task 2: It is assumed that there is a mixture of water, acetone and table salt in a vessel and that any necessary equipment for the separation of the mixture into its components is available. Teachers are asked to describe the procedure they would follow in order to separate the components of the mixture, describing the necessary equipment. Some relevant data are also given:

	Water	Acetone	Table salt
Melting point (°C)	0	-95	801
Boiling point (°C)	100	56	1413

Task 3: Teachers are asked to describe the procedure they would follow in order to determine the solubility of table salt in water, describing any equipment necessary for this purpose. The following reminder is also given: the solubility of a substance in water is the maximum amount of this substance that can be dissolved in a given quantity of water (usually 100 g) at a specific temperature.

Results

How often do teachers use hands-on science activities in school?

Table 1 shows primary teachers' views on how often they used hands-on science activities in school. The teachers seemed to participate in such activities to a significant degree, although male and female teachers did it to a different extent. Male participants estimated that they used hands-on science activities more often than their female colleagues, supporting the view that male teachers are more practical than the female ones (Arnot et al., 1999). The difference between the two genders is found to be significant [$\chi^2(3)=15.766$, $p=.001$].

Table 1. Teachers' answers about their use of hands-on science activities in school.

Category	Teachers' answers	Number of teachers, N, and Percentage (%)		
		Total	Male*	Female*
1	Often	93 (40.8)	53(54.6)	40(30.5)
2	Sometimes	125 (54.8)	43(44.3)	82(62.6)
3	Never	8 (3.5)	1(1.1)	7(5.4)
4	No answer	2 (0.9)	0(0.0)	2(1.5)

*Percentages refer to the total number of male teachers or female teachers, respectively.

Teachers' descriptions regarding hands-on science activities

Task 1

For task 1, teachers were asked to determine the density of an unknown liquid. Their answers were categorized according to their correctness and completeness (see Table 2). In category 1, 44.3% of teachers described in detail a correct and complete procedure. Another 27.2% of the teachers (category 2) gave a correct, but not totally complete answer, as they responded similarly to those in category 1, with the exception of the determination of volume: They did not specify how the volume is measured (i.e., by the volume graduations on the beaker). Teachers who fell into category 5 (sub-categories 5a and 5b) of Table 2 could not determine the density of the liquid because either they used the total weight of beaker and liquid in their calculations without subtracting the tare (sub-category 5a) or they did not proceed to the division of *mass* by *volume* (sub-category 5b).

Table 2. Teachers' categories according to their answers in tasks 1, 2, 3.

Cat.	Characteristics of the teachers' descriptions		Task 1	Task 2	Task 3	Score
	Correctness	Completeness	N (%)	N (%)	N (%)	
1	Correct procedure	Complete description of the procedure	101 (44.3)	**1a.** 17 (7.6) **1b.** 40 (17.5)	49 (21.5)	4
2	Correct procedure	Almost complete description of the procedure (*Clarifications in some points are missing or they are implied*)	62 (27.2)	68 (29.8)	74 (32.5)	3
3	(Mainly) correct part of the procedure	Partial description of the procedure (*A part of the procedure is missing*)	-	52 (22.8)	-	2
4	Correct outline of the procedure	Description of an outline of the procedure	-	25 (11.0)	66 (28.9)	1
5	Incorrect procedure/ No answer	Complete or incomplete description/ No answer	**5a.** 39 (17.1) **5b.** 17 (7.5)	4 (1.7)	7 (3.1)	0
6	Miscellaneous answers		13 (5.7)	22 (9.6)	32 (14)	0

Note: Sub-categories 1a and 1b, and 5a and 5b are explained in the text.

Task 2

Besides the teachers' ability to carry out the activity, the use of the appropriate equipment and materials was also an issue in task 2. The categorization (Table 2 for task 2) was not simple as there was too great a variety in teachers' working and their descriptions. Generally, in all tasks, teachers had problems in expressing their thoughts and in using appropriate words or terms as well, something that had also been pointed out in other studies in Greece (Papageorgiou and Sakka, 2000). For instance, *boiling*, *evaporation* and *heating* were used as synonyms or in an incorrect way by the teachers. Furthermore, these problems in teachers' descriptions sometimes resulted in incoherent answers, which is one of the main reasons for the formation of the category *miscellaneous* in each one of the three tasks (see Table 2).

Among the categories of Table 2 for task 2, teachers' descriptions in the 1a and the 1b sub-categories were correct and complete in carrying out the activity; the main difference between them was the use of the necessary equipment and materials. Teachers in the 1b sub-category did not explain what equipment and materials are needed for this activity (in all or in parts of the procedure) and how they are used.

Teachers' descriptions in the rest of the categories for task 2 did not report any use of the necessary equipment and materials. In category 2, the descriptions did not explain how the collection of the vapors of a substance could be achieved. Teachers of category 3 gave descriptions, which were mainly correct but incomplete, as they did not explain how the isolation of the components of the mixture is achieved. It should be mentioned at this point that, although teachers seemed to get along task 2 in general terms, the part of the procedure concerning the isolation of the components of the mixture (all or part of this procedure) was a problematic one for a remarkable number of them, independently of the categories of Table 2 (for task 2). In cases where teachers referred to this part, the main difficulties concerned the condensation of vapors (water and acetone) and their collection. However, although teachers' descriptions at this point were 'alternatives', 'unclear' or 'incomplete', they could be considered as acceptable to a certain degree, because primary teachers are not expected to have any specific knowledge about such procedures. Some of these teachers' descriptions are: "*In order to condense vapors, we use a cold plate…*", *"…we collect vapors in a vessel, where, they are left in order to cool," "…vapors are collected through a long tube, in order to be condensed*", "*…we use an apparatus similar to that we use in the production of tsipouro"* (*tsipouro* is a traditional Greek drink produced by distillation), etc.

It should also be noted that, although in categories 1-3 boiling and melting points were used by the teachers, there were some cases in category 3 (and in category 6, as well), where the use of these properties was incorrect. For instance, a teacher used the melting point of acetone (-95 °C), instead of the boiling point 56 °C, for the isolation of acetone. As Johnson (1996) has underlined, these are indications of an incomplete understanding of the concept of *substance*. As del Pozo (2001) also has suggested, prospective teachers have difficulties in concepts like *substance* and *mixture*, as well as in relationships between concepts concerning the composition of matter, in general.

Finally, there were a number of teachers, who simply described a general scheme of the procedure (category 4).

Task 3

In task 3, as also in task 2, the use of the appropriate equipment and materials was also an issue (besides the teachers' ability to carry out the activity). Teachers' answers, which are presented in Table 2, were also categorized according to their correctness and completeness.

The 123 teachers, who fell into the categories 1 and 2, described satisfactorily a procedure to find the solubility of the table salt in water. In fact, the differences between these two categories are that: a) in the 2nd category there wasn't a clarification at the end of the procedure of how the solubility is obtained (or it was implied) and b) the use of the necessary equipment and materials was not always complete. However, in both categories, teachers proposed some ways, 'scientific' or 'alternative', in order to measure the amount of table salt dissolved in water, which is a crucial point indicating their ability to carry out this activity. Some of these 'alternative' ways included: addition of small pre-weighed parts of salt in water; use of a volumetric tube and calculation of the amount of salt on the basis of volume; addition at once of a pre-weighed quantity of salt and weighing of the precipitate after filtration, etc. Also, 28 out of these 123 teachers described a more 'scientific' way, based on the weighing of an amount of salt, pre- and post- the dissolution of the necessary part of it in water.

The teachers placed into category 4 did not describe any particular procedure for the determination of the solubility of the table salt in water, and they only referred to its dissolution (with no reference to the quantification of the dissolved salt or to the equipment).

Comparing tasks - How 'gender' is related to teachers' descriptions?

In order to compare teachers' descriptions among the three tasks, a scoring scale was constructed, common for all tasks, on the basis of the particular characteristics of the categories throughout the tasks. For this analysis, only the ability of the teachers to carry out the activity was considered, as the use of the necessary equipment and materials was an issue only in two of the three tasks (tasks 2 and 3). As Table 2 shows, this is a 5-points scoring scale (0-4), each step of which has a distinct difference from the next one regarding the correctness and the completeness of the teachers' descriptions. Using this scale, a corresponding score (0-4) was awarded for each one of the categories of Tables 2 for tasks 1, 2 and 3, respectively. The percentage agreement between the two coders was 94.7%, 96.0% and 95.2% for the tasks 1, 2 and 3, respectively. After discussion, the percentage became 100% for each of the three tasks. Assuming that there is also an impact of the 'gender' on participants' descriptions in each one of the three tasks, a set of Multiple Analysis of Variance (MANOVA) was applied on the relevant scores.

Data analysis showed that the main effect of teachers' descriptions regarding the activities is significant, $F(2,223)= 7.642$, $p=.006$. As Figure 3 illustrates, teachers had more difficulties in carrying out task 3 than the other two tasks, and task 2 was found to be more difficult than task 1. However, it is worth noting that these results do not take into account teachers' descriptions concerning the use of the necessary equipment and materials. Thus, results could be different if teachers' difficulties regarding the use of appropriate equipment and materials for the isolation of the components of a mixture (especially for the condensation of vapors), which was revealed in task 2, were included in this comparison.

Figure 3. The main effect of teachers' descriptions regarding the activities.

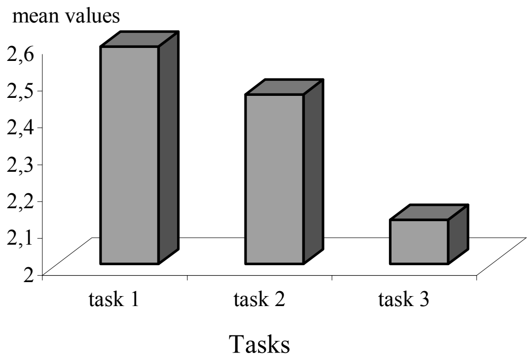
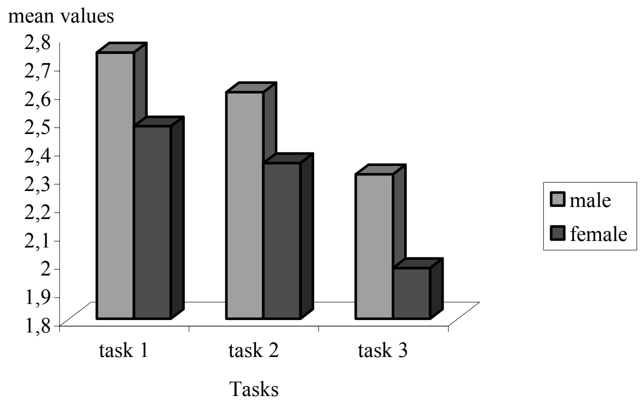


Figure 4. The teachers' descriptions of the three tasks in relation to their gender.



As far as the relation between 'gender' and teachers' descriptions is concerned, it was found to be significant $F(1,226)=3.942$, $p=.048$. Figure 4 shows that the male teachers were found to give more efficient descriptions regarding the procedures of the three science activities than their female colleagues. However, as it has been already reported, male participants estimated that they had used hands-on science activities in school more often than female ones, a fact which had also an impact on their descriptions. As a result, we could not draw a definite conclusion about the main reason for this particular effect on their descriptions of carrying out the three tasks.

Nevertheless, taking into account the teachers' descriptions concerning the use of the necessary equipment and materials (in tasks 2 and 3) the general impression (according to the qualitative analysis of the data) is that male teachers are working in a more practical way, whereas female teachers are more theoretical (and more general) in their descriptions. In particular, in task 2 (Table 2) 82.4% of teachers of sub-category 1a (where there is a use of the necessary equipment and materials) were male, $\chi^2(1)=11.91$, $p=.001$. In sub-category 1b and the two other categories that follow (where the use of the equipment and materials is progressively declined), the proportion of female teachers increased, making no significant the difference between the two genders. In these categories, the corresponding percentages of female teachers were 60.3%, 61.5% and 60.0% per category, respectively. Similarly, in task 3 the majority of teachers in category 1 of Table 2 were male (33 out of the 49 teachers, χ^2 (1)= 8.91, $p=.002$); the opposite holds true for category 2 (49 out of the 74 teachers were female, χ^2 (1)=3.44, $p=.043$.), whereas there is not a statistically significant difference between the two genders in the rest of the categories of Table 2 for task 3 [category 4 (37 out of the 66 teachers were female), category 5 (5 out of the 7 teachers were female), category 6^h (21 out of the 32 teachers were female)].

However, it should be noted that the above analysis relates to teachers' descriptions of carrying out practical work; they are not statements about any teachers' science skills. As a result, any further conclusion drawn for the gender differences in the ability to carry out hands-on sciences activities would be unjustified.

Conclusions and implications

According to the results of this study, although the Greek primary teachers' descriptions regarding some hands-on activities on chemistry topics ranged from a more correct and complete level to a more generally descriptive and incomplete level, it seems that the majority of teachers could carry out such activities to a satisfactory degree.

As far as the teachers' ability to carry out these activities is concerned, task 3 appeared to be the most difficult. This could be seen as an indication that teachers were not used in working on such activities where a number of issues are involved at the same time, such as the dissolving of a substance in water, the measurement of the dissolved amount of this substance, and the effect of the temperature on its solubility. Indeed, hands-on activities which are related to chemistry topics, and especially to solubility, are not very common in primary education, in Greece at least (Greek Pedagogical Institute, 1999).

However, if the teachers' descriptions regarding the use of the necessary equipment and materials are the issue, task 2 appeared to be the most problematic, especially its part concerning the isolation of some of the components. A possible reason might be that this activity has the greatest number of steps related to changes of state. In these steps, the use of 'specific' equipment is required, which is not very familiar to primary teachers. Among these changes of state, condensation seems to be the most difficult for the participants. This may have contributed to the result that task 2 was also the second in difficulty among the three tasks concerning the teachers' ability to carry out the activities. Indeed, although there are no data available about primary teachers' conceptions concerning condensation in literature, this change of state has been reported as one of the most problematic for children (Johnson, 1998; Paik et al., 2004; Papageorgiou and Johnson, 2005). Given that teachers' misconceptions have common characteristics with those of children (Kruger and Summers, 1988; Kokkotas and

Hatzinikita, 1994; Papageorgiou and Sakka, 2000), primary teachers could also have difficulties in understanding condensation, as was seen in the problems in carrying out the corresponding part of task 2.

The gender of the teachers seems to have played a significant role in their descriptions. Additionally, male teachers stated that they had used such activities in school more often than female ones had. As a result it is not clear whether it was the male teachers' more frequent use of hands-on science activities in school that made them better able to describe a procedure of a science activity, or whether it was due to the male identity being connected more to practical sciences, while the female identity is connected to more theoretical sciences (Arnot et al., 1999). However, as has already been discussed, the above results indicate 'gender differences' regarding only the teachers' descriptions of science activities, they offer no insight into any connection to science skills.

Although we acknowledge the simplicity of our research instrument and the limitations of this study as they have been already reported, the findings can suggest some answers to the main questions of this work. These seem to be promising for a successful incorporation of such science activities in the National Curriculum for Primary Education. However, the implementation of science activities in primary schools is also a matter of primary teachers' training on scientific ideas. As it is reported by a number of researchers (Jarvis et al., 2001, 2003; Lavonen et al., 2004) an appropriate in-service training program can significantly improve teacher practice in school. More effective science training programs mean more teachers able to use science activities frequently and effectively towards a better teaching and learning science.

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