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Valuable insights on curriculum, teaching, and learning may be gained from research, and it is the aim of this section to bring significant research information to the attention of science teachers, with a view of helping them in their important work.

Turkish Pupils' Conceptions of the Conservation of Mass During Phase Changes

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Abstract

This paper describes year 6, 8 and 11 (13, 15, and 17 years old respectively) Turkish pupils' conceptions about the conservation of mass during phase changes. Three hundred Turkish students ranging in age from twelve to eighteen years were the participants in this research. Two open-ended questions were asked to obtain pupils' understanding about the conservation of mass during the transformation of ice into water and water into water vapour. As well as these written responses, ten students of various year groups were interviewed. Three main categories such as correct answers, partially correct answers, and incorrect answers, were used in the description of results. The analysis of both written responses and interviews indicated that pupils of all ages had more difficulties in understanding the conservation of mass during the transformation of water into vapour than the transformation of ice into water. The findings of this study have several implications for both teachers and curriculum designers.

Keywords: Science Education, Conservation, Altevnative Conceptions.

Introduction

Several studies have been carried out in order to find out pupils' understanding about phase changes. Most of these studies addressed pupils' conceptions about the conservation of water as a substance during its transformation (Osborne & Cosgrove, 1983; Russell, Harlen, & Watt, 1989; Bar & Travis, 1991; Bar & Galili, 1994). However, very few studies were carried out to find out pupils' views about the conservation of mass during phase changes.

Stavy (1990) investigated 6-15 age range Israeli pupils' problems in understanding conservation of weight by certain tasks such as melting, evaporation, dissolving of sugar and plasticine deformation tasks by the interviews. Approximately 65% of 13-14 year old students could conserve the weight both in the melting of ice and evaporation of acetone. However, weight was conserved in the plasticine deformation task by about 90% of 13-14 year old students. She found that the majority of students, who gave incorrect answers to the melting of ice task, mentioned that water was lighter than ice. Similarly, they believed that gas had no weight or gas was lighter than liquid in the context of evaporation of acetone.

Similarly, the study of Hatzinikita and Koulaidis (1997) explored 10-18 age range Greek pupils' views about conservation of weight of water when it is transformed from liquid to gas and liquid to the solid state by a multiple-choice questionnaire but requiring extended explanations for pupils' reasons for their choice. Approximately 23% of 11-12 year old and 48% of 16-17 year old students could conserve the mass when water changes into water vapour, while 21% of 11-12 year old and 47% of year 17-18 year old students conserved the mass when water changes into ice. Most of the pupils who did not conserve the mass mentioned the increase in mass during the transformation of water into ice and decrease in mass when water turned into water vapour.

As stated above, little research has been undertaken about students' conceptions of conservation of mass during phase changes. This study investigated Turkish children's views on the conservation of mass during phase changes and how these views evolve with age, starting from 12 until 18 years old. In particular, this study concentrated on the following issues:

(a) What are Turkish students` conceptions about the conservation of mass when ice turns into water?

(b) What are Turkish students` conceptions about the conservation of mass when water turns into water vapour?

Methodology

Three hundred Turkish students ranging in age from twelve to eighteen years were the participants in this research; fourty students were year 6 (12-13 years old), sixty were year 8 (14-15 years old) and two hundred were year 11 (17-18 years old) pupils. Twelve and fifteen year old students in the sample were studying Integrated Science, while the seventeen and eighteen year olds were studying all the three science subjects (physics, chemistry and biology) separately. The participants, comprised of 47% of female and 53% of male students, were from two high schools and one secondary school in a middle-class area in central Denizli, a city in the west of Turkey. The sample had average ability. Two questions were asked in order to obtain pupils' understanding of the conservation of mass during phase changes.

Question 1

There is ice, whose mass is 100 gram, in a closed jar. We put this jar into a hot place until all the ice turns into water. What do you expect the mass of water, obtained from heating the ice, to be?

a) Less than 100 g

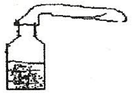
b) More than 100 g

c) 100 g

Explain your choice ....

Question 2

As seen from the figure below, a balloon is tightly fitted at the top of a jug that contains water. The jug, water and the balloon weigh 300 grams altogether. We heat the jug until all the water turns into vapour.



What do you expect the weight of jug with the balloon and vapour to be?

a) 300g

b) Less than 300g

c) More than 300g

Explain your choice..................

Both of these questions were designed similarly to the questions in the study of Hatzinikita and Koulaidis (1997). Question 1 and question 2 assess students' understanding of conservation of mass when ice turns into water and when water turns into water vapour in a closed system, respectively. The visual representation of the event in the 2nd question was included to make easier for students to understand this question. As well as students' written responses given to these questions, data were collected by the interviews of ten students of various year groups.

Results

The analysis of data was based on the formation of categories according to the students' responses given to these questions. Three main categories of responses were used in the description of results in this study.

1. Correct answers: This category involves completely correct answers.
2. Partially correct answers: This involves explanations which may be correct, but

containing either inadequate or incorrect explanations as well.

3. Incorrect answers: They involve completely incorrect explanations, uncodeable responses, and no-responses.

Main categories involve a set of sub-categories falling into the same category.

Discussion

As Tables 1 and 2 show, the number of pupils giving accepted responses increases across the age groups. Incorrect responses tend to be more frequent among younger pupils for both of the questions. Correct answers for both of these questions seem to have a sharp rise around the age of 17-18, year 11.

Another result these tables show is that students of all ages seem to have better understanding of conservation of mass when ice turns into water than the transformation of water into the gas state. This may be because understanding the conservation of mass during the transformation of water into the gas state requires more abstract thinking, since water vapour is unseen when water is turned into the gas state. As seen from Tables 1 and 2,

Table 1

Summary of the Percentages of Types of Responses for Question 1

Type of response	Year 6	Year 8	Year 11
Correct answers			
**100g, correct explanations*	*50%*	*56.7%*	*79.5%*
Partially correct answers			
**100g, no explanations*	*5%*	*5%*	*1%*
Incorrect answers			
**Less than 100g*	*32.5%*	*26.7%*	*15%*
**More than 100g*	*12.5%*	*11.7%*	*3%*
**No-response*	*None*	*None*	*1.5%*

Table 2

Summary of the Percentages of Types of Responses for Question 2

Type of response	Year 6	Year 8	Year 11
Correct answers			
**300g, correct explanations*	*17.5%*	*26.7%*	*66.5%*
Partially correct answers			
**300g, no explanations*	*2.5%*	*5%*	*2%*
Incorrect answers			
**Less than 300g*	*67.5%*	*43.3%*	*21.5%*
**More than 300g*	*10%*	*23.3%*	*5.5%*
**No-response*	*2.5%*	*1.7%*	*4.5%*

50% of year 6, 56.7% of year 8, and 79.5% of year 11 students could conserve mass during the transformation of ice into water, whereas this dropped to 17.5%, 26.7% and 66.5% among the year 6, 8 and 11 students, respectively, with the problem of the conservation of mass when water turns into the water vapour. This is in contrast to the research of Hatzinikita and Koulaidis (1997) where students of all ages gave slightly more correct explanations in the problem of the weight estimation, when water changes into water vapour than the one when water changes into ice.

Most of the explanations relating to the conservation of mass for both the transformations of water into vapour and ice into water fall into the following categories:

i) Mass is conserved in the phase changes.

ii) Since the system is closed, water vapour or ice cannot leave the system or nothing can be added, therefore it remains there.

This kind of thinking that pupils have when dealing with the problems related to the conservation of mass was also reported by Piaget and Inhelder (1974).

iii) Consideration of the formula, d=m/V (especially in the situation of melting of ice).

They mentioned the decrease in the volume of water and increase in the density of water when ice melts, thereby the constant mass.

Although these three views were common, some pupils mentioned the reversibility of the water vapour or water as the reason for the constant mass:

> "Water in the jar evaporated and became vapour, but after a while, if we cool the jar, water vapour turns back into the water again. Therefore, mass is constant."

This is the thinking children have when dealing with the conservation of mass mentioned by Piaget and Inhelder (1974). Similarly, few students referred to the particulate ideas to explain the conservation of mass:

> "It is still 300g. Because the number of the molecules in the system didn't change."

However, I am not sure all the pupils indicating that "mass is constant in the physical changes" really know that gases also have mass. Students may have just memorised this as a rule without thinking about its meaning. For example, an interview[1] with a year 11 student supports this:

> I: Does the vapour have any weight according to you?
> S: No, it has no weight.
> I: In the 2nd question, you told the mass to be conserved, how is the mass conserved?
> S: Hmmm, (reads the question). I mean mass. I don't know for example when water becomes ice, it becomes liquid or solid, change phase, mass is conserved, it has a certain mass.
> I: But the vapour hasn't got any certain mass.
> S: Laughs, then vapour must also have mass when we think it.

Likewise, pupils who could not conserve the mass tended to indicate the decrease of mass more often with both of the problems of the phase change of water from solid to liquid and liquid to the gas state. For example, most of the year 6 pupils (67.5%) mentioned the decrease in the mass of the system when water turns into the water vapour, whereas this view decreased to 21.5 among the year 11 students. Decrease of mass when ice turns into water is also the most common answer among the pupils of all ages giving incorrect explanations.

Pupils' explanations for this view fall into the following groups:

i) Water vapour has no mass.

ii) Mass of water vapour is less than the mass of water.

iii) Liquid substances weigh less than solid ones (change from the state of solid into liquid).

These were the common views held by pupils to explain the decrease of mass when ice turns into water or when water turns into the water vapour. It appears that the thought of water to be lighter than the ice, or gases to have no mass, comes

1. In the interview transcripts, "I" represents the interviewer and "S" represents the student (Interviewee)

from the belief system of pupils as a result of experience in the physical world, since many solid substances are denser in everyday life and gases are unseen. The studies of Stavy (1990) and Hatzinikita and Koulaidis (1997) also point out these intuitive rules pupils have.

However, all of the students may not generalise the non-existence of the mass of vapour to all gases as seen from the explanations below of one year 8 pupil during the interview:

Y: Does vapour have any mass?
S: Mass of vapour, as far as I know, it doesn't.
Y: What about air?
S: Air, there is oxygen, I think it has.
Y: Is it because of oxygen?
S: Oxygen, nitrogen, and the other gases.
Y: Do they have weight?
S: I think so.
Y: So, air has mass.
S: Maybe.

This may be because of the awareness of the mass of oxygen, hydrogen, and the other gases, since they usually encounter these in mass calculations in science classes.

As well as the above explanations, some pupils gave the following reasons for the decrease of mass.

iv) Evaporation occurs (during the transformation of ice into water) making the mass lower.

Despite the correct scientific knowledge, evaporation can occur at any temperature, the thought of the evaporation causing the decrease in the mass of water comes from the lack of the consideration of the system as a whole (ice in a closed container), instead they focus on the component of the system (ice) experiencing the phase change. This view was not reported by any of the research findings related to this area.

v) Consideration of the formula, d=m/V (in case of melting ice).

Some of them mentioned the increase in the volume of water thereby the decrease in mass by thinking about the constant density. This implies that these pupils do not know the density change in phase changes and they are not aware of the decrease of volume in water, which is a special case, since normally the volume of substances increase as they turn into liquid.

In addition to these, some pupils supported their view, which includes the non-conservation of mass in phase changes, by referring to the particulate nature of matter. The following is one of the examples taken from the transcript of the interview with a year 6 student:

I: Ok, you said here less than 100gr. Because particles of solid substances are dense. Do you mean it is more in number or what?
S: Hmmm, when ice melts, its mass decreases therefore. That is, when a liquid substance melts, that is solid substance, that is particles inside, hmmm...
I: Particles inside?
S: Particles inside, since they are denser in a solid matter, when it is melted, its mass decreases.
I: By saying dense, did you mean they are high in number or they are close to each other?
S: Closer to each other.
I: What does mass mean according to you?
S: Mass, hmmm, number of particles in a substance.
I: Is the number of particles less in liquids when compared to the solids?
S: They are looser, therefore, it is less.
I: According to you, may this be the reason for the decrease in mass?
S: Sorry?
I: You said there are fewer particles in liquids.
S: Yes.
I: Does it cause decrease in mass?
S: Yes.

On the other hand, most of the pupils indicating the increase in mass when water turns into vapour gave explanations regarding the increase in the volume of the vapour, thereby the increase of mass. Some of the younger pupils thought the expansion of the balloon to be the reason for increase in mass. It may be because they have associated the largeness of the balloon with the heaviness of it causing an increase in mass. The confusion of mass with size or volume was also mentioned in another research (Holding, as cited in Driver, Squires, Rushworth & Wood-Robinson, 1994). For example, one year 8 pupil explained in the interview:

I: You said in the second question, the total mass of vapour, bottle and the balloon, is more than 300gr. As its reason, volume of the vapour is more. Is there any kind of relationship between volume and mass according to you?

S: Volume, volume is the place it occupies in the space, since it occupies a place in the space; its mass is the same.

I: Then, you mean, these two are the same. As the volume of a substance increases, does it mass increase as well?

S: Yes, increases, I think.

Similar views indicating the increase in volume causes an increase in mass to explain the non-conservation of mass of a closed system have also been reported by the research of Hatzinikita and Koulaidis (1997).

Although the above explanations were mostly given in this research, some students were also confused with the concepts of mass and density. They gave such explanations:

"The ice in the poles float on the sea, therefore the mass of ice is smaller than the water. So, the mass of water increases when ice turns into water."

Conclusion

The analysis of students' responses showed that nearly half of the year 6 and 8 students could conserve the mass during the transformation of ice into water, whereas most of the year 11 students had no difficulty in understanding the conservation of mass when ice melts into water. However, pupils of all ages had more difficulties in understanding of the conservation of mass during the transformation of water into water vapour. Especially, few of the year 6 and 8 students could give correct explanations. Most of the students, who could not conserve the mass, when water turned into water vapour, thought gases had no mass or weighed less. Similarly, they thought liquids weighed less in case of the transformation of ice into water. An experiment, which is designed to show that mass is conserved during these events, can create conflict with these children's views and convince them to accept the conservation of mass during phase changes. In addition, it was found that pupils had misconceptions about some basic scientific topics, such as confusions about volume, mass, and density. The distinction between these basic concepts should be made clear in science classes.

Both science teachers and curriculum developers should consider these difficulties students experience and suitable teaching strategies to teach conservation of mass during phase changes should be designed by considering, rather than ignoring, students' misconceptions. The elicitation of these misconceptions can be through small group discussion work, whole class discussions, and wall posters prepared by the pupils or drawings to represent their thinking. Discrepant events can help the conceptual conflict, since it brings dissatisfaction with their old conceptions. To illustrate: some students in this study thought that mass was not conserved when water turned into water vapour. The experiment, showing that mass is conserved during the transformation of water into water vapour, may bring about dissatisfaction with their existing ideas. In addition, exchange of ideas among pupils can also cause them to be aware of different views for the explanation of the same phenomena. As Driver, Squires, Rushworth and Wood-Robinson (1994) state, discussion with peers may provide the opportunity for children not only to make their ideas explicit, but also build on each other's ideas and take their thinking forward. In addition, pupils should be given the opportunity to apply their developed ideas to a variety of situations, both familiar and novel. This is necessary for them to understand the fruitfulness of the new conception. When they see the usefulness of this new idea, it will make more sense. Therefore, the application of conservation of mass to daily lives can be helpful for children to understand this concept.

In addition, the particulate model could help students to give meaningful explanations to conservation of mass during phase changes. Students should be encouraged to use the particulate model to explain the phenomena related to the conservation of mass during phase changes in a consistent manner.

Curriculum should be designed to give more time for student investigation and discussion of their ideas in the curriculum. Besides, the curriculum should provide pupils with the chance to change their thinking progressively towards a more complex one throughout their school years. This means the science or chemistry curriculum do not need to build complete understanding of a conceptual area the first time it is taught. The continuity of the curriculum should be provided through building the sophisticated ideas upon basic ideas (Taber, 1995). For example, the concepts of mass, volume, and density should be introduced to the pupils before explaining the conservation of mass during phase changes. Similarly, conservation of mass during the transformation of ice into water should be explained to the pupils before introducing the transformation of water into water vapour since the latter is more abstract.

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Various Science Teachers Associations in the world, such as the British ASE, the American NSTA, the American AAPT (Physics Teachers), and many others have their own publishing and dissemination programs as well as websites with teaching materials and strategies. We would like to invite officers of Associations of small and big countries in different parts in the world to write brief overviews about the publishing and dissemination programs. These will then be published in the next few issues of *Science Education International.* Even a few paragraphs will be fine as I can merge contributions from different countries.

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