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Helping Middle School Students to learn the Kinetic Particle Model.

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ABSTRACT

A lot of science teachers think that the kinetic particle model is too difficult and abstract for middle school students. During the last years, a lot of new methods of teaching science, called constructivistic methods, have been introduced. In this paper, we present a way of teaching the particle model by using several of these constructivistic methods combined with more traditional teaching methods. We used the model to explain daily life phenomena and problems in connection with experiments. We have taught the unit to students from grade 6 to 9. The students have answered an extensive written questionnaire concerning the study. The teachers have also answered a written survey and have been interviewed as well. Students´ knowledge has been tested in two tests one month after the unit was finished; one using everyday language and one using scientific language. The project is still under evaluation, but thus far we can draw some conclusions: Middle school students are in fact mature enough to learn the essence of the kinetic particle model, and the teaching methods applied in the project had a stimulating effect on girls interests in physics.

The purpose of this study:

- to get some experience in new teaching methods of presenting science
- many researchers have focused on the "gender gap" in science education, i. e. to what extend and why boys like science and do better in science (especially physics) than girls when in Middle School(Sjoeberg 1986, Sjoeberg 1988, Kahle 1988). Do these new methods affect this? Do girls like some of these methods better than boys or vice versa? (Gianello 1988).
- to see if it is possible for middle school students to get a sound understanding of the essence of the kinetic particle model

METHOD

We have made a unit consisting of a teachers guide of 31 pages and worksheets and testsheets of 28 pages. The author has first taught a preliminary version first with one class of Grade-7 students and than one class of Grade-6 students. The unit was intended to take 12 lessons. However, most teachers reported that they used 14-15 lessons.

The knowledge of the students was tested when starting the unit, during the unit and at the end of the unit. The students were also to be tested with two different tests one month after the unit was ended. The first of these tests used everyday language and the other used concepts from the model.

Nine classes in the Norwegian 9-year school in northern Norway started the unit with students from Grade-6 to Grade-9 in the spring of 1993. Six classes (109 students) completed the unit, 3 classes did only parts of the unit because they started it too late in the school year. Only four classes (56 students) started the unit early enough so that they could take the final tests one month after having finished the unit.

The teachers were given four introductory lessons to the unit by the undersigned. When the teachers had finished teaching the unit, they answered a thorough written questionnaire and were afterwards interviewed by the undersigned.

THE KINETIC PARTICLE MODEL

The idea that matter consists of particles was put forward by the greek philosopher Demokrit about 400 years before Christ. Under Aristotle (350 years B. C.), however, the theory of matter as a continuum became dominant. Early in the 19th century the kinetic particle theory was developed. The idea to the kinetic particle model came mostly from studies of gases. The essence of the kinetic particle model can be summarized as follows: *"Matter consists of tiny particles, called molecules, that are constantly in motion."*(Lee, Eichinger, Anderson, Berkheimer, Blakeslee, 1993). In this study we used the term particle instead of the term molecule.

A lot of daily life phenomena seemingly unconnected can be explained by using the kinetic particle model, e. g.:

- solids expands when heated - because the particles vibrate and take up more room

- the smell of perfume - because some perfume particles escape from the bottle and travel quickly through the surrounding air particles
- food coloring spreads in water - because the particles of the two substances are in constant motion and will hit each other, and consequently the color will be distributed
- spilt water on the floor disappears - because the water particles are in motion and escape from the surface of the water and mix with the air particles

Several topics in science depend on the kinetic particle model in order to get a meaningful understanding: osmosis and diffusion, photosynthesis, the water cycle, ecological matter cycling, the Second Law of Thermodynamics, and so forth.

There are good reasons why middle school students should get the opportunity to learn this model. However, the model is not stressed in the most commonly used science textbooks in Norway, and is not used to explain e. g. osmosis. The authors obviously think that this model is to difficult for students aged 12-16. This view is not only a Norwegian one. In a report from a study in California Linn and Songer (Linn & Songer, 1991) have this to say about the kinetic particle model for middle school students: "We expected this model to be too abstract for students and also to offer explanations at a level of analysis that did not apply to the results of their experiments or to their observations of the natural world." Instead of the kinetic particle model they used a heat-flow almost similar to the old "caloric" theory.

In this study we try to get an answer to the question: Are students aged 12-16 mature enough to learn the essence of the kinetic particle model?

THE TEACHING METHODS

Constructivistic teaching.

Our view of learning is that of the constructivist: *It is the student himself/herself who constructs his/her knowledge. The theories and expectations which the student already has of a phenomenon are determing the observations that the student makes.*

Like a lot of other researchers we view science learning as a complex process in which new information interacts with prior knowledge and beliefs to produce conceptual development and change (Possner, Strike, Hewson & Gertzog, 1982; Osborne & Wittrock, 1985; Pines & West, 1986; Smith, Blakeslee & Anderson 1993).

A lot of research has revealed that students develop their own ideas about natural phenomena often before these phenomena have been taught in school. They have constructed these ideas through everyday experiences and social interaction. These ideas, called everyday conceptions (some people use misconceptions, preconceptions, spontaneous reasoning, alternative frameworks about these ideas) often differ markedly from those in the school curriculum. Some of these everyday conceptions persist often even after the student has been taught the scientific conceptions at school!(Driver, Guesne, & Tiberghian, 1985). It is therefore important that the teacher knows about the students´ everyday conceptions to discuss them with the students and design experiments which the everyday concept can´t explain. The students are often not aware of their own everyday conceptions. To talk about these ideas is maybe the best way to change them - a well known principle in psychiatric treatment!

When teaching a new conception/phenomenon we tried to find out which ideas (prior knowledge) the students already had about this phenomena by answering worksheets. It is also important to find out what kind of knowledge the students develop during the teaching unit, so we can prevent them developing new everyday conceptions (misconceptions)! Through class discussions and reviewing individual student written work, the teacher should be able to follow the students conceptional development.

Doing experiments.

We had picked out experiments which are easy to do and could easily be explained by the kinetic particle model. Most of the experiments could be connected with the everyday life of the children, like e.g. blowing up balloons or dissolving sugar in hot water. The experiments were done by two or three children working together as a group. For each experiment there was a worksheet telling the students what to do. Most often they had to make a hypothesis of what was going to happen and also to explain why by writing on the worksheet. See Appendix A.

Making the model more concrete.

The kinetic particle model is very abstract and to make it more concrete we used several methods:

A. Students playing particles. When playing particles the students had to move according to the same rules as spheres do when colliding with each other or colliding with a wall. To control the "temperature", we played music and the students had to follow the rhythm. We used mostly slow rock so that the students did not hurt each other when colliding.

B. Drawing particles. The student drew particles as small spheres and in this way showed how they imagined the particles in e.g. a gas or a solid.

C. Using macroscopic models. We used peas in a beaker as a model for fluids. By vibrating the beaker, the peas got in vibration. Vibrating peas in the beaker became a good model for a fluid showing fluid properties like horizontal surface and filling up a beaker of any form from the bottom. By putting into the vibrating beaker with yellow peas some green peas the student got an concrete model of diffusion of dye in a fluid.

Students formulate.

Many of us have discovered that when you have to teach, formulate or explain some difficult concepts in your own words, you get a better understanding of these concepts yourself. In this unit we used a lot of methods to get the student to formulate:

A. Discussions in the classroom. After an experiment was finished the teacher and the students discussed what had happened. The students were encouraged to explain the experiment using the particle model.

B. Summary by drawing concept maps .The students and the teacher summed up the concepts by drawing a concept map (Novak & Gowin, 1984) after about every fourth lesson (See Appendix E). Drawing the concept map was a collaboration work: The teacher drew the concepts on the blackboard and the students drew in their books. Students and teacher had to agree about how the map should be and should draw the same map. In this way all student acquired the same concept maps and misunderstandings could be removed in the discussion (Okebukola and Jegede, 1988; Roth and Roychoudhury, 1993; Willerman and Mac Harg, 1991).

C. Writing about being particles. The students were assigned to write small stories like: "My life being an air particle trapped in Kari`s balloon".

D. Homework on demonstrating and explaining experiments. After working with a concept at school, students did an experiment about this concept which they had to show to parents and/or other adults at home. They also had to explain the experiment by using the kinetic particle model! The adults were instructed to be skeptical to the explanation and to discuss the explanation with the student. The kinetic particle model was new for most of the parents/adults, and in this way the students were teachers to their parents/adults! See Appendix B.

E. Making predictions and explaining experiments on worksheets. In connection with the experiments at school, the students had to make predictions about what would happen in the experiments, and after the experiments were finished they had to explain why it happened. They discussed the predictions and explanations first in the experiment group, but also had to write it down on their own worksheet. See Appendix A.

THE CURRICULUM

The different states of matter were taught in this order:

Gas.

First the students have to explain which model they have for a gas. This test is almost the same as the one used by Novic and Nussbaum (Novic and Nussbaum, 1981; Nussbaum, 1985).

Afterwards the students experiment with syringes, air in balloons, warming up and cooling down air.

By working with syringes, the students discover that air can be compressed and that the continuum model of air which some of them believe in can´t be correct. The explanation that air consists of particles with space between looks like being easy to end up with by the students. The concept that the particles are in motion is introduced in connection with explaining the pressure against the piston in a syringe. By playing particles between desks and moving a log as the "piston", the students "experience" how the pressure is built up:

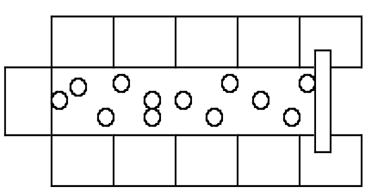


Figure 1. Students playing particles in a "syringe". The "syringe" is made up by desks and the "piston" is a log.

Later on we introduced the connection between the motion of the particles and the temperature by showing how much air expands when being warmed up in the experiments. This was also dramatized by students playing particles.

We also introduced smell as gases and we did a class experiment to find out how fast perfume smell spreads in the classroom. This we also dramatized by some students playing smell particles and the rest of the students playing air particles.

During the gas part of the unit the students got two home assignments:

- demonstrate and explain why air can be compressed in a syringe (Appendix B)
- demonstrate and explain how air expands when being heated in a bottle

<u>Fluid.</u>

Through class discussion the students agreed that a fluid like water have to consist of particles, because water could become gas (vapor) which they already had agreed was made of particles. By putting water in a syringe the students realized that water could not be pressed together like air, and so the water particles had to be very near each other.

The students did a lot of simple experiments which they discussed and explained by applying basic kinetic particle theory:

- putting some water on a desk and having the same amount of water in a baker near by, and see which disappears first.
- putting some food color in warm and cold water and observe that color spreads faster in warm water.
- dissolving a colored salt in warm and cold water and observe that the salt dissolves and spreads faster in warm water.

We also dramatized some of these experiments.

Before finishing the fluid part of the unit, the students got homework where they should demonstrate to their parents/adults that sugar dissolves faster in warm water than in cold water. They were also to explain this by using the kinetic particle model.

<u>Solid.</u>

The unit ended by looking at some of the properties of solid matter. The students, now used to the particle explanation, suggested that the particles in a solid stick together. When playing particles they had to use their arms holding each other on their shoulders:

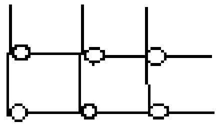


Figure 2. When dramatizing a solid the students hold each other on their shoulders, but they can still move a little by bending their elbows.

The students did some simple experiments which they discussed and could explain by the particle model like:

- melting of ice by putting some ice cubes in a beaker early in a lesson.
- conduction of heat by putting a metal rod in a flame.
- tearing a thin metal wire into pieces
- expansion of solids by warming a metal wire

Not all these experiments were dramatized, but the students were to discuss in class how the experiments could be dramatized.

Before finishing the unit the students were assigned an experiment to do at home. They were to put some icecubes in a pan, heating it on the stove until they melt to water and eventually the water boils and wait until almost all the water "disappears" to gas. They were also to explain this to their parents/adults by drawing a concept map using the concepts involved.

COMMENTS AND EXPERIENCES

Drama activities.

Teachers who had used dramatization before concluded that using the rhythm in music to set the "temperature" was an improvement. Some of the teachers reported that they had some difficulty with this method because some students became embarrassed and some students thought it was too childish. Most of the teachers reported that this activity worked well. In some of the classrooms especially arranged for science, the desks could not be moved, so they had to find another room for dramatizing or had to drop it altogether

The advantage of this method is that each "particle" can move by itself, but there could be a problem if the students think that the particles of matter are living bodies. In the final test 34 of 75 students (45%) agreed with the statement:

"All particles are alive". From an investigation in Newfoundland, Canada (Griffith & Preston, 1992) 16 of 30 students (53%) also thought that particles are alive. This subject was not mentioned in the unit and we don´t know if it was discussed in the classes. In the preliminary version taught by the author it was discussed just a few minutes, and there only 1 of 16 students (6%) held the opinion that particles are alive.

We therefore conclude that dramatization probably doesn´t cause more students to think that particles are alive. By discussing this subject with the students they will probably easily change this belief.

Playing particles was a good way of introducing the student to the kinetic particle model. We think that drama will enrich science teaching, especially when teaching abstract theories, but also other parts of science (Gianello, 1988). The activity is, however, not easy to conduct, so teachers need some training in this way of teaching science.

Writing activity.

In these activities the students have to write small stories about being particles. To help starting the storywriting we gave them some words they could use in the story. See Appendix C. From table I we see that this activity was more popular among girls than among boys with a statistical significance of $p<.05$ on a two-tailed t-test. By reading the stories the teacher could uncover misunderstandings of the kinetic particle model like e.g. some particles die when they get too cold. Such misunderstandings could then be discussed in class.

All of the 9 teachers who were interviewed about this activity think it is a good activity to be used in teaching science.

Summarize by drawing concept maps.

After about every 4th lesson we made concept maps. The concept maps were made during discussion in the class. In connection with the discussion the teacher drew a map on the blackboard and the students drew the same map in their books. In this way misunderstandings could be removed during the discussion and no one made wrong concept maps.

Drawing the concept map collaboratively was stimulating to the discussion of the concepts in the class. This was reported from most of the teachers. Especially collaborative activity with construction of concept maps have also been shown elsewhere to help students in meaningful learning (Okebukola & Jegede, 1988; Roth and Roychoudhury, 1993). Some of the teachers also said that the concept map was a good way for themselves to get an overview of what they had taught!

Homework to do and to explain experiments.

As we se from table I, these two activities were on average the least popular of the activities among the students. But as we see from the big Standard Deviations, the students disagree a lot about these activities. On the other hand, we see from table II, that these activities were very much appreciated by the parents! The parents even think that they have learned something by the model! Maybe this is a way of getting scientific theory better known in society?

Some of the teachers experienced that before doing an home experiment, many students asked the teacher a lot of questions about the kinetic particle model. This assignment has obviously motivated some of the students to learn the model more thoroughly! In this unit we did not prepare the students to explain the home experiments, but it is probably wise to do so by e.g. drawing concept maps just before the students get their assignment. In this way students might be better prepared to teach their parents!

Doing homework and explaining experiments to parents/adults is a good idea, but we need further research in order to improve this activity. It is also important to find experiments interesting both for the students and for their parents. The students should be better trained at school before they teach their parents/adults at home.

TABLE I
Mean Scores and Standard Deviations of students who have answered the question on a Likert scale from 1 (not agree) to 5 (agree).

Questions	Boys (N=55) X_b	S.D	Girls (N=54) X_g	S.D.	Differences (X_g-X_b)
I liked this unit	3.56	1.12	3.63	.88	.07
I liked doing the experiments	4.35	.78	4.07	.89	-.28*
I liked playing particles	3.24	1.15	3.15	1.37	-.09
I liked doing experiments as homework	2.67	1.36	2.85	1.14	.18
I liked explaining the particle model to adults	2.51	1.23	2.61	1.14	.10
I liked writing about being particles	2.74	1.22	3.28	1.23	.54**
I liked drawing particles	3.35	1.27	3.48	1.04	.13
I liked answering the worksheets	3.11	1.31	3.43	1.04	.32
I think I understand the particle model	4.16	.79	4.30	.66	.14

* p< .05 on one tailed t-test. ** p<.05 on two tailed t-test.

TABLE II
Mean Scores and Standard Deviations of parents (females and males) who have answered the question on a Likert scale from 1 (not agree) to 5 (agree).

Questions	Female (N=51) X	S.D	Male (N=32) X	S.D.
The home experiments did not take much of my time	4.36	0.94	4.47	0.95
To be shown and explained the home experiments were a fine experience	4.26	0.87	3.97	1.15
The home experiments were a good way to see what my child learned in science at school	4.51*	0.80	4.09*	1.20
I think I have learned something about the particle model from what the child explained	3.72	1.08	3.47	1.19

*p< .05 on one tailed t-test.

Are girls favored by these teaching methods compared to boys or vice versa?

Boys have been found to outperform girls in almost every science achievement measurements, particularly in physics (Walberg, 1967; Comber & Keeves, 1973; National Assessment of Educational Progress, 1978; Fleming & Malone, 1983; Erickson & Erickson, 1984; Levin, Sabar & Libman, 1991). Several researchers suggest that girls are less interested in science than boys because the experiments we normally do in schools are more connected to boys´ interests and their way of life. (Sjoeberg, 1986; Sjoeberg & Imsen, 1988; Levin, Sabar & Libman, 1991).

In this unit most of the experiments have been connected to the daily life phenomenon of the students like blowing up balloons, testing smells, dissolving sugar in water and using the refrigerator and the freezer. Every experiment could have been done in a kitchen, so the experiments are directed to traditional girls´ daily life as much as to boys´. Looking at table I, we see that both boys (4.35) and girls (4.07) selected "doing experiments" as their favorite activity. The boys, however, are here more positive than the girls and the difference is statistically significant with $p<.05$ on a one tailed t-test.

Looking at the other activities in table I, we find that the writing activity has the only significant difference with $p<.05$ on a two tailed t-test! The girls obviously like the writing activity better than the boys do. The differences between the boys and the girls on the other activities are not statistically significant, but the girls are generally more positive than the boys.

In the Norwegian part of the Second International Science Study (Sjoeberg, 1986) the students answered the question: How do you like physics at school? On a scale from -1 (Bad) to +1 (Good) the average among the boys was 0.28 and among the girls -0.31 in Grade-9! From table I we see that in this unit students give a positive evaluation: the boys (3.56) and the girls (3.63)! There is no statistically significant difference between the boys and the girls.

Both girls and boys appreciate this way of learning. Compared with ordinary physics courses girls obviously like this way of learning physics better than the traditional way.

Can Middle School students get a sound understanding of the kinetic particle model?

On the statement "I think I understand the particle model" the students answer on a scale from 1 (not agree) to 5 (agree) on average 4.16 (boys) and 4.30

(girls). Also the Standard Deviation are low and there is no statistical significance ($p<.05$) between boys and girls on this statement. See Table I. We therefore conclude that the students mean that this model is not too difficult for them.

When asking the teachers, they all answered that this model is not too difficult for average middle school students. However, some of the teachers stressed in the interview that the particle model normally will be too abstract for a few students in a class. Most of the teachers suggest that Grade-7 is the best grade to introduce this model.

The results from the test using only everyday language and mostly everyday problems are summed up in table III (Everyday test). 57 students have answered the tests one month after the particle unit was finished. We have made 3 categories:

1) Students not using the particle model in an acceptable way, 2) Students using the particle model, but on less than two problems in an acceptable way and 3) Students using the particle model in an acceptable way on at least two problems. When students are using the particle model on at least two of the Everyday test problems, we think that he/she has accepted and developed the model in a way that it is useful to explain some of the problems in everyday life. All together there were 8 problems to be answered, most of them from Haidar and Abraham (Haidar and Abraham, 1991). See Appendix D for some of the problems.

About 25 % of the sample did not use the model and a lot more boys (32%) than girls (17%). 75% used the model on at least one problem, but only 63 % used the model on more than one problem.

Table III

Result of the test carried out one month after finishing the unit using everyday problems and language. The students had to answer using their own formulations. See Appendix D.

Answering quality	Girls		Boys		Total	
	X	%	X	%	X	%
Students not using the particle model in an acceptable way on any problem	5	17	9	32	14	25
Students using the particle model, but on less than two problems in an acceptable way	5	17	2	7	7	12
Students using the particle model in an acceptable way on at least two problems	19	66	17	61	36	63
Sum	29	100	28	100	57	100

We think this result is acceptable and we agree with the teachers and the students that middle school students are mature enough to learn the essence of the kinetic particle model in Middle School.

The Final test 1 month after finishing the unit using the concepts from the model is not analyzed in detail yet. But a preliminary analysis show that only very few student are now using the continuum model, compared to more than half of the students when starting the unit. When starting almost no student thought that matter is composed by tiny particles which are moving. Now more 90 % hold this view one month after having finished the particle unit! However, there are still a lot of everyday concepts among the students like e.g. particles in a stone do not move and that particles of ice is heavier than particles of vapor! Though we think the unit is a good start for learning the kinetic particle model for middle school students, some students still have some way to go!

CONCLUSIONS AND IMPLICATIONS

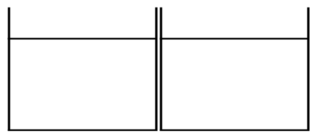
The connection between model and reality is not easy to develop. We agree with Haidar and Abraham, 1991 (exchange "chemistry" with "science"): "Hands-on experiences in chemistry (science) are important, but not sufficient for the understanding of the concepts. Students need instruction that will help them develop the link between the macroscopic observations in the laboratory (or in everyday life) and the microscopic models that chemists (scientists) use to explain them." In this unit we have used a variety of teaching methods to help student develop this link. The teaching strategies reported here are probably more powerful in combination than they are in isolation as also claimed by other researchers (Smith, Blakeslee & Anderson, 1993).

Some of the methods like writing, drawing particles, using macroscopic models, drawing concept maps and discussions are easy to manage for the teachers and it shouldn´t be difficult to use them.

Drama is a more demanding classroom activity. Science teachers are usually not acquainted with it and therefore need some education in drama in order to use this activity effectively. The homework activities to do and to explain experiments are very encouraging , but we need to develop this activities further. The students should be trained in these methods in Colleges of Education.

We think that these teaching methods will enrich future science teaching, but the method number one should still be the traditional: **doing laboratory work**!

Appendix A.
Student worksheet.
Spreading of a dye in warm and cold water.
Go to the hot faucet and get warm water and to the cold faucet and get cold water in the two beakers:



Cold water Warm water

The teacher is going to put a few drops of red dye into each of the beakers.
What do you think will happen with the dye in the two beakers?

....
Why do you think this will happen?

....

....

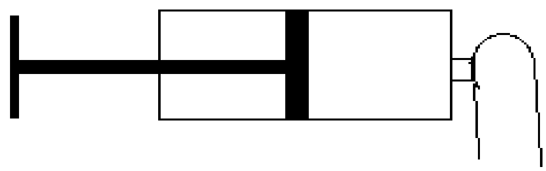
The teacher will put the drops into your beaker when you have answered the questions above.
Study carefully what is happening in the two beakers. Write down what is happening:

....

....
In which of the beakers does the dye scatter fastest?

....

Appendix B
Student worksheet.
Homework: Air in a syringe.



Show the syringe to the adult(s) and what happens when you compress the air and then let the piston go!
Let also the adult(s) try this!

You have to explain to the adult(s) the kinetic particle model of air.

Draw particles in the picture of the syringe. Explain that the particles move and how they move!

Explain to the adult how this model can explain why we can compress the air in the syringe!

Explain also why the air resists being compressed and why we feel the pressure from the piston!

Tell also the adult(s) about experiments, demonstrations and about how we played particles in the class!

Appendix C.
Student worksheet.
Story writing: The changes of my life.
You are one of the ice particles in the experiment. Write a story about how it is to be an ice particle which first melts into a water particle and eventually evaporates to a steam particle.
Try to use some of these words: keep hold of, vibrate, moving around, get free, small velocity, high velocity, collide, particles, reflect.

Appendix D

Some of the questions from the test using everyday language. These questions were answered at least 1 month after finishing the kinetic particle course.

Question 1.

A spoonful of sugar is added to a glass half filled with water. After a while the sugar has dissolved in the water.

Write a paragraph to explain what happens when sugar dissolves in water:

Question 3.

Write a paragraph to explain the similarities and the differences between warm water and cold water:

Question 4.

A clear plastic cup is half filled with water. The cup is set on a table where it will not be moved. After the water is still, a few drops of food coloring are carefully added to it. After a period of time it is observed that the water is uniformly colored blue.

Write a paragraph to explain how the food coloring mixes in the water:

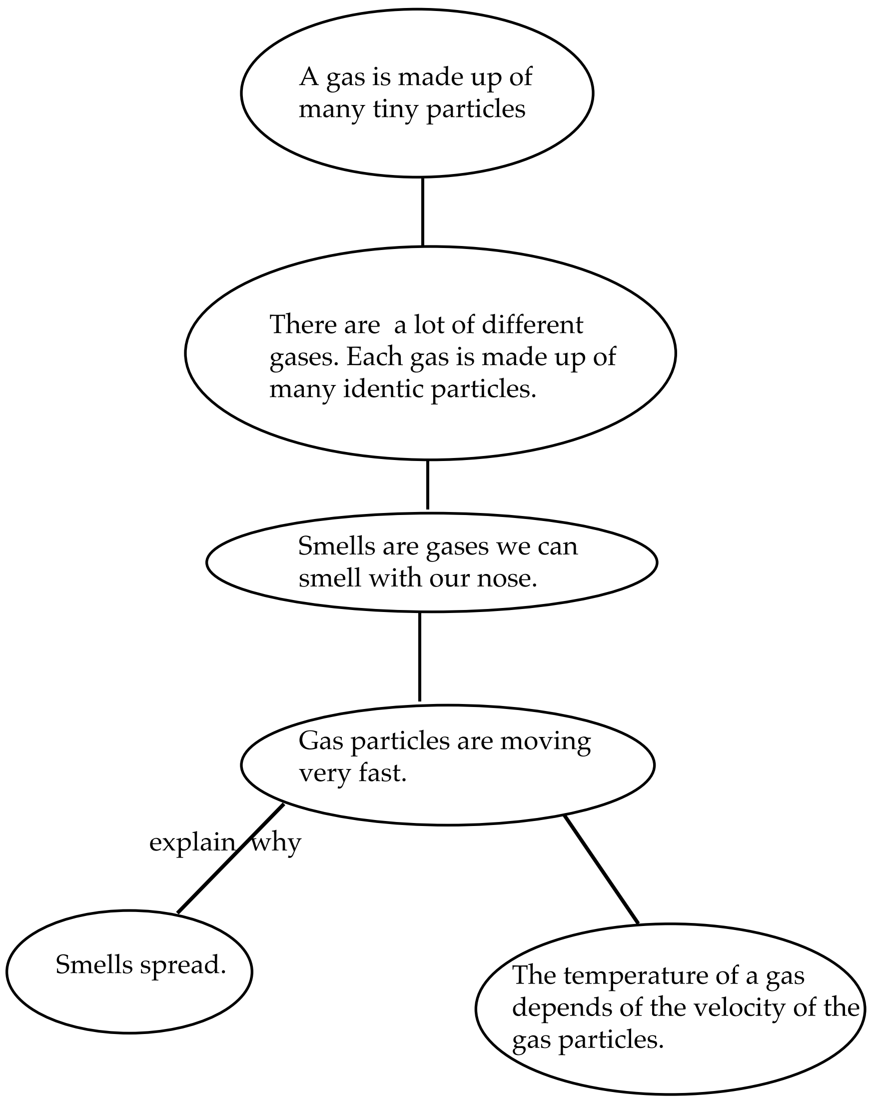
Question 8.

Water exists in three forms: gas (water vapor), liquid, and solid (ice).

Write a paragraph or more to explain the similarities and the differences among the three forms of water:

Appendix E.

Concept Map after the fourth lesson.



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