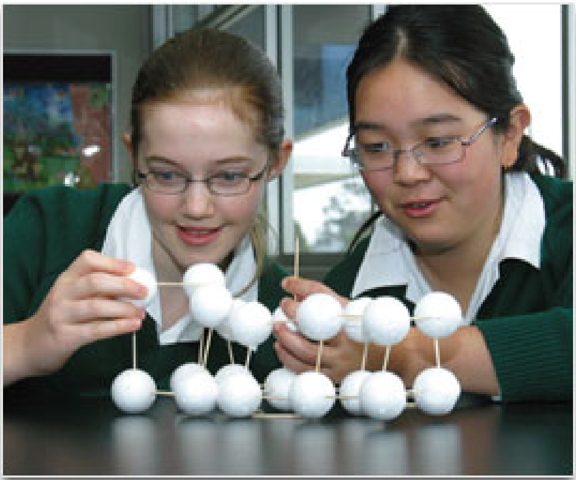
The particle theory

Critical teaching ideas - Science Continuum F to 10
Level: Working towards level 8

Student everyday experiences

Students have no experience with the idea that some things (particles) can't be divided. If sand is ground up into tiny pieces it is still sand. There seems no reason why the dividing can't keep on going to smaller and smaller pieces.

Even when children are introduced to the idea of matter being made of particles, most consider there is still 'stuff' between the particles and that something like air fills the empty space. After all when liquid is poured from a glass so that it is empty it still contains air (see Hannah's question) (- Loughran Berry Mulhall & Gunstone, 2001).



Particles are often assumed to behave in the same way as the substances they make up. For example particles themselves can swell, shrink and melt; the particles in stone are harder than the particles in rubber. Many students consider that ice molecules melt to little droplets of water.

The scientific view

The properties of matter can best be explained using a model in which all materials are composed of tiny particles (atoms, molecules, ions).

There is empty space between particles and particles are constantly moving (their speed is changed by temperature).

Changes of state involving solids, liquids and gases can be explained by changes in arrangement and speed of the particles.

Critical teaching ideas

- All matter is composed of tiny indivisible particles too small to see.
- These particle do not share the properties of the material they make up.
- There is nothing in the space between the particles that make up matter.
- The particles which make up matter are in constant motion in all physical states.

Students will have a range of explanations for phenomena they have observed. They should move towards the view that a key feature of the particle model is that it was invented by early scientists as a model that explains a wide range of phenomena. Some can also be explained by a continuous model, but some cannot. Presenting this scientific view through the use of diagrams and models alone has been shown to achieve relatively little conceptual change in students. Essentially the particle model is a way of thinking about matter that requires exploratory discussion to help build student understanding.

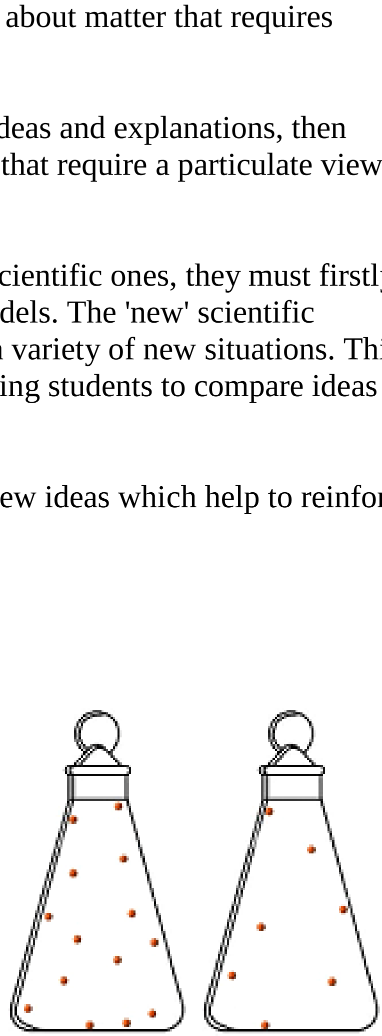
A suggested teaching approach is to first ascertain student ideas and explanations, then provide motivating experiences which require explanations that require a particulate view of matter.

If students are going to change their views to the accepted scientific ones, they must firstly become dissatisfied with the usefulness of their existing models. The 'new' scientific conception must be plausible and intelligible and useful in a variety of new situations. This will involve facilitating the exchange of views and challenging students to compare ideas including the scientific perspective.

Finally, provide opportunities for students to test out their new ideas which help to reinforce their usefulness.

Teaching activities

Bring out students' existing ideas.
Asking students to draw what they think they would see if they were "shrunk" to a tiny size and placed in a drop of water will bring out whether or not they understand particles (if they draw particles). Further questioning can elicit from those who do draw particles, what they think is between the particles as well as why they drew particles. Later on, other probes can bring out how students are thinking now. Students can be asked to sketch the particles in a flask of air and then sketch the flask when half the air has been removed.



Encourage students to identify phenomena not explained by the (currently presented) scientific model or idea.
"Challenge the right answer". It is impossible to "prove" the particle model and very difficult to have students develop it from experimental phenomena without a lot of prompting. One approach is to present the standard diagrams of particles in the three states of matter with a few lines of notes on each. Leave out some of what is normally presented, such as comments about attractive forces, say that this is something that scientists believe and ask students to find phenomena that this does not seem to explain. Typically this gets them thinking seriously about the model and generates a need for some more features (such as attractive forces).

Promote reflection on and clarification of existing ideas.
The initial meanings that students form for the particle model are rarely truly particulate. Provide opportunities for students to articulate the meanings they have and refine these in what is an iterative process. Thought experiments can help students formulate views about particles such as, imagine a tiny person as small as a particle sticks a needle into a particle of water or gas. Would the water leak out? Would the gas burst out and make a hissing sound?

Challenge some existing ideas.
Predict Observe Explain sequences can challenge students thinking on the compressibility of gases and liquids. Ask students to predict how much a syringe full of air can be compressed by one person. Call for reasons why, do it, and call for explanations in terms of the particle model. Then repeat with the syringe full of water. This is the more powerful in that many students believe that water will be compressed noticeably, yet it isn't, and the particle model does explain (and predict) this.

Practice using and build the perceived usefulness of a scientific model or idea.
Students come to see the particle model as more useful than a continuous model and gradually they should observe a range of phenomena which require the particle model to help explain them.

Squeezing syringes containing gas (coloured gas if possible) can show increasing intensity of colour and the idea of particles being pushed closer together.

Mixing methylated spirits and water can help to show there must be space between particles (50ml + 50 ml = around 95 ml). Give a hint when calling for explanations: methylated spirits particles are bigger than water particles.

Debates and interpretive discussions which encourage students to develop explanations for new situations using the particle theory can help in moving towards a scientific concept of the particle model e.g. explain why popcorn pops, why can we smell onions at a distance when cooking, and why does a syringe containing brown gas appear darker when compressed.

Students can use their particle model to explain how scents, air fresheners and perfumes are able to spread from the source to all regions in a room.

Students can begin to explain how hydraulics work in terms of the particles in a liquid being free to move but close together.

Clarify and consolidate ideas for/by communication to others.
Model making: students construct particles out of play dough or plasticine and then by drawing on butcher paper students demonstrate how the particles are arranged in each phase. Students can then demonstrate what happens as a substance changes from a solid to a liquid to a gas using the play dough particles.

Role playing different phenomena such as perfume particles when the bottle is open or the particles in melting ice require students to build a concrete meaning for propositions about particles. Videoing these and debriefing helps pick up things not yet assimilated. Group activities where students construct posters in groups to explain phenomena with posters presented to the class and creative writing where students imagine they are particles in different situations can both provide opportunities for students to discuss and modify their prior views.

Promote reflection on how students;' ideas have changed.
Students should be encouraged to reflect on how their views have changed.
(Loughran Berry Mulhall & Gunstone, 2001 and Brook Briggs & Bell, 1983)

Vignette
Hannah's question (from Loughran, Berry, Mulhall and Gunstone)

The students were busy making models to show how they thought the particles were arranged in solids, liquids and gases. Prior to this class they had learned that the particles in a solid are packed closely together in a regular pattern, that in a liquid they are still close together but the arrangement is not regular and has spaces which enable the particles to slide over each other, and that in a gas the particles are far apart with no pattern at all.

Hannah, one of the more able student raised her hand:

"Ms Smith you know how particles are further apart in a gas - what's in the gaps?'

Ms Smith had been waiting for a question like this. If it had not come from the students she would have raised it herself. It was only after that she had been teaching for some years that she had begun to realise that the answer to this question was a difficult one for many students to imagine. Each time she taught the Particle Theory she found that even when students 'knew' from their lessons that nothing was actually between the spaces in a gas, they said or asked things which indicated they actually thought there was something in the gaps.

Ms Smith told the class; "Let's think about Hannah's question. Put on your magic glasses (these are used to imagine things that cannot normally be seen) and tell me what you see when you look at a gas?'

'Gas particles with big spaces between them'

Ms Smith: 'What do you see when you look at the big spaces?'

'Lots of tiny air particles!'

As Ms Smith had often reflected, in many ways this kind of response was not surprising. If we poured all the water out of a jug, we would say there was nothing in it. Yet we would understand that it contained air. Thus in everyday life, 'nothing' was often a synonym for air.

Ms Smith then asked the class to predict what would happen to the weight of a balloon when it is blown up (many students hold the belief that air is nothing which is a barrier to understanding the particulate nature of matter)

After the balloon was blown up and its increase in weight noted. A student raised her hand; 'So air particles actually have weight?'

Ms Smith; 'Yes air particles have weight so air is actually something! Now let's think again about Hannah's question about what's in the gaps between gas particles. If you could look at the spaces between gas particles with your magic glasses, what would you see.

One student called out: 'Other little air particles!

Hannah raised her hand: 'No I disagree. Air is something and is made up of particles so there can't be air between particles - if there were, you would never have a gas!' Ms Smith:' Yes so what would you see if you could look at the spaces between the particles in a gas?'

'Nothing!' a number of students chorused.

Further resources

Science related interactive learning objects can be found on the FUSE Teacher Resources page. To access the interactive learning object below, teachers must login to FUSE and search by Learning Resource ID:

- **Types of Matter: solids, liquids gases –** students select samples from an outdoor setting and magnify the substances to atomic level so that the particles they consist of can be seen. They then sort the substances into groups based on how the particles are arranged and how they move, classifying the substances as solids, liquids or gases. Learning Resource ID: HSTCW7