Title: Atoms and molecules: Do they have a place in primary science?
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In primary science, topics such as matter, air, water and changes of state are generally introduced through hands-on activities using everyday resources. Many children find it difficult to understand basic science concepts such as states of matter (solids, liquids and gases) and everyday phenomena such as evaporating and dissolving. Their understanding can be influenced by the things they use in everyday life or by ‘everyday’ usage of words. For instance, they consider solids as hard and rigid and have difficulty classifying soft, malleable and granular solids. They think liquids are ‘runny’, so viscous liquids cause conceptual difficulty. Many tend to associate gases with gas cookers. The literature has reported that children see matter such as flour as continuous and do not realise that matter is made up of particles. They will draw a block for solids, a partially filled container for a liquid, and wavy lines to represent a gas.

**What research tells us**

Some Greek research

Hatzinikita and Koulaidis (1997) explored children’s ideas about conservation during changes in the physical state of water. They administered a questionnaire to a large sample (4297) of primary and secondary school children in Greece. The questionnaire consisted of seven items on children’s ideas on evaporation, boiling, condensation and conservation of mass. In responding to the items about ‘drying of water in a dish’ and ‘drying of laundry’, about 20% of the 10–11 year-olds thought that the water had disappeared or been ‘absorbed by the dish’. Less than 20% of the 13–18 year-olds thought that water was transformed into gases rather than being ‘absorbed’ or ‘disappearing’ during the drying process. When asked about the composition of bubbles in boiling water, around 20% of 10–13 year-olds thought that ‘bubbles consist of heat’, while about 25% of 14–18 year-olds thought that ‘bubbles consist of hydrogen and/or oxygen’.

**SPACE research**

In one of the Science Processes and Concept Exploration (SPACE) projects, Russell and Watt (1990) conducted a classroom-based study of 5–11 year-olds’ ideas on evaporation and condensation. The teachers used everyday phenomena such as ‘dropping water level in a large container over a period of time’ and ‘breathing out in cold air or against a cold window’ to investigate their pupils’ concepts of evaporation and condensation.
Questions asked included ‘Where has the water gone?’, ‘What has made the water go?’ and ‘Can the water be made to go faster/slower?’ Examples of the pupils’ responses are given in Box 1.

Findings from Australia
The Australian Council for Educational Research (ACER) study conducted by Adams, Doig and Rosier (1991) found that very few grade 5 pupils appeared to use the particle model to explain differences between states of matter, or processes such as evaporation, condensation or chemical change. Nevertheless, some of these pupils seemed to believe that many chemical and physical changes could be explained by referring to the non-observable. Recent research (e.g. Johnson, 1998) indicates that understanding the structure of matter in terms of particles, such as atoms and molecules, can enhance pupils’ conceptual understanding of the properties of matter and some chemical phenomena.

Building on these findings
These results seem to show that the understanding most primary-age children have of the structure of matter does not intuitively relate to its particulate nature. They tend to interpret the chemical world using some naive ideas, though some use abstract ideas.

A few educators (Leisten, 1995; Skamp, 1998) have argued that particle ideas should be introduced gradually by building on children’s naive questions about matter, and by the accumulation of examples and specific instances of the behaviour of matter. For example, when upper primary children study the concepts of evaporation and condensation, they might be introduced to the particulate explanation on how the water changes from one state to another. Whether some upper primary children could start to appreciate some of the properties of chemicals in terms of their particle nature is an area in which teachers should tread carefully. Could the particle model of matter be the underlying ‘big idea’ in a primary science teacher’s mind as he or she interacts with children on the relevant topics? Depending upon the specific content and context and the age of the children, some teachers may find it appropriate to help them think of the world in terms of particles.

Using the particle model – two examples

Water
Water is made up of many water molecules, each containing two hydrogen atoms and one oxygen atom combined together chemically. Using a circle (o) to represent a water molecule, the different arrangements of water molecules in ice, liquid water and water vapour can be used to explain the different physical properties of water in the three states (Box 2). For further details of the particulate structure of water in terms of atoms and its unusual properties (e.g. ice is less dense than liquid water, whereas for most substances the solid state is more dense than the liquid), see Segal (1989, pp. 162–165).

Air
Air is made up of particles. Box 3 shows how the air particles are arranged inside and outside a can. Children are asked questions, such as ‘What happens when some of the air in the can is removed?’, ‘Does the mass of the can remain the same after some air is removed?’, and so on. They are encouraged to use particle model ideas to explain their answers. Box 4 shows two possible particulate diagrams of the air inside the can after some air has been removed. Only one of them is scientifically acceptable.
**THINKING & FEELING**

**Box 2 Particulate representation of the three states of water**

In steam the water particles are very spread out. This is why steam can move about.

In a solid (ice) all the particles are packed tightly together. The particles are held together in a block and there is very little movement.

In water, the particles are irregularly arranged and can slip past each other. This is why water cannot 'stand up' on its own and takes the shape of its container.

**Box 3 Air inside and outside a can**

**Conclusion**

Teachers may consider using the particle model to enhance conceptual understanding of phenomena observed in everyday life or encountered in hands-on activities. The teacher needs to decide when this approach is appropriate, in terms of content, context and the ability of the children. Audio-visual aids (e.g. models, analogies, simulations) may be useful to supplement drawings of particles. Dynamic graphical presentation of change of state is effective in demonstrating the movement of particles and the attraction forces between particles. Explanation of some everyday phenomena or observations, for example dissolving, diffusion of perfume, movement of smoke, spread of powder or flowing water, in terms of particles can enhance children's conceptual understanding in science.

**Box 4 Air in the can after some of the air is removed**

Which diagram, (a) or (b), do you think correctly represents the particles of air after some air has been removed?

- (a) Fewer particles spread out
- (b) Particles at the top of the can have escaped through the tube

**References**


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Atoms are the smallest form of matter that still retain their properties. Atoms consist of protons, neutrons and electrons, with neutrons and protons forming their nucleus and electrons orbiting around it. Atoms combine with each other to form molecules. The combinations are in a particular ratio and can be with atoms of the same type or different types. For example, O\textsubscript{2} is a molecule formed by the combination of two oxygen atoms. When atoms combine with each other, they can do so by forming ionic bonds or covalent bonds. In the former, electrons are lost and gained by different atoms, as in sodium chloride, NaCl. In the case of a covalent bond, atoms share their electrons, as in the case of oxygen gas (O\textsubscript{2}). Hope this helps.

Questions

What do the electron-dot structure of elements in the same group in periodic table have in common with each other? They have the same number of valence electrons.

To become a negative ion, does an atom lose or gain electrons? It gains electrons.

What is the primary difference between a chemical bond and an attraction between two molecules? A chemical bond is many times stronger than an attraction between molecules.

Are induced dipoles permanent? No, induced dipoles are temporary, they are induced only when they are in close proximity to a water molecule, or another dipole.

Why do minerals have such a high melting point?

In science education, the topic of states of matter is one of the basic subjects; it is first taught in primary school and continues through science education at all levels. The topic is also emphasized in the document on national American standards (National Research Council, 1996), which refers to the properties and the changes in the structure of matter (Rice, 2005; Sadler et al., 2013; Skamp, 2009). This makes clear that teaching about states of matter is of vital importance.