

Salient points from the literature about understanding the water cycle

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Planet Earth consists of complex and finely balanced interacting systems. These systems affect and are affected by human activities. It is important that students develop an appreciation of how these systems work so that they become aware of the possible consequences of human activities. The water cycle is one of these systems.

Understanding of the water cycle is dependant on understanding evaporation and condensation.

A comprehensive research literature suggests that although evaporation and condensation are simply the processes of change of state of water from liquid to a gaseous state and vice versa these processes are not easily understood, especially by younger students.

It seems that young children rely heavily on sensory information when reasoning about matter (Kind, 2004) and because gases are often invisible they are particularly problematic for young students. Children develop intuitive ideas about solids and liquids but do not seem to form ideas about gases spontaneously.

Younger students will often believe:

- that when matter disappears it ceases to exist;
- weight is not an intrinsic property of matter – weightlessness can be accepted.

Even much older students can struggle explaining the processes of evaporation and condensation because of misconceptions about the way matter is made up of particles. If a student does not appreciate particles are moving, it is hard to explain what happens when a gas is heated or cooled.

Science ideas:

- All matter is made up of discrete particles.
- The space between particles is empty.
- Particles are in constant random movement.

Alternative ideas:

- Students assign macro-level properties to the particles, e.g., students think that when a liquid is heated the particles themselves expand.
- The space between particles is filled by gas or dust.
- The uniform distribution of particles in a gas is due to attractive or repulsive forces, not constant motion.

The British research project, SPACE (Science Processes and Concept Exploration), showed that students held a range of alternative but coherent ideas to explain evaporation. These ideas can be organised into 3 broad categories.

Students' understanding of evaporation

Examples

No understanding of the conservation of matter.

- The student focuses on the remaining water – the evaporated water has simply ceased to exist. It has dried up, gone, or disappeared.

The water still exists, but has gone somewhere else. The water is still in liquid form.

- A human or other animal has taken the water.
- Some other agent, e.g., the sun took it away.
- The water penetrated a solid, e.g., it leaked through the saucer.

Water changes into a vapour.

- Water changes into some other perceptible form, e.g., mist, fog, etc.
- Water changes into some invisible form. (This is the scientifically correct explanation).

Boiling seems to be an easier process to understand and teaching of this should perhaps precede evaporation. However, when asked what the bubbles in boiling water are made of, students aged from 12-17 displayed a range of ideas:

- The bubbles are air.
- The bubbles are heat.
- The bubbles are oxygen/hydrogen.
- The bubbles are water vapour (the scientifically correct response).

Alternative ideas about condensation

When asked to explain why moisture forms on the outside of a glass of cold water, students (8-17) also illustrated a range of alternative ideas about condensation:

- Water comes through the glass.
- Coldness comes through the glass.
- The cold surface and dry air (oxygen and hydrogen) react to form water.
- Water in the air sticks to the glass.

The scientifically correct explanation is that some of the water vapour in the air condenses into tiny droplets of water when it touches the cold glass.

Students' understanding of evaporation and condensation influences their perception of clouds and rain.

For instance:

Explanation of clouds

Clouds are sent by God or come from some other place.

Clouds are made from vapour from kettles or from the sea boiling.

Clouds are filled with sea water.

Clouds are created from water vapour. (When water vapour cools tiny droplets of water form and accumulate on dust and other particles in the atmosphere.)

Ideas about evaporation

No understanding of evaporation

Familiarity with boiling but not evaporation

Understands that water moves but not that it changes state

Understands evaporation and condensation involve changes of state.

Children who see clouds as holding water in its liquid form are likely to explain rain as clouds bumping into each other or bursting. The scientific explanation of rain is that the tiny drops of water in the clouds join together until they have enough mass for gravity to pull them to earth.

Key concepts for understanding the water cycle:

- Water can exist in the form of water vapour, an invisible odourless gas.^[1]
- Air contains this invisible vapour.
- When water vapour condenses tiny droplets of liquid water form. If enough of these droplets join together, gravity causes them to fall as rain.
- The amount of water vapour in air can vary.
- The rate of evaporation is influenced by heat, atmospheric pressure, and wind.
- Evaporation separates water from solids which are dissolved in it. (This is why rain is not usually salty even though much of the water that becomes rain has evaporated from the sea.)
- Earth is a “closed system”. There is a finite amount of water. Water constantly cycles between the surface of Earth and the Earth’s atmosphere.

Bar (1989) suggests that initial ideas about the water cycle should be introduced about age 9 when some understanding of evaporation has been established. If the topic of the water cycle is revisited about age 12 students may be then ready to understand rainfall in relation to gravitation. This requires an understanding that vapour has weight. Later still students should be able to understand the relationships between air pressure, ascending water vapour, and condensation. Understanding the water cycle involves bringing together a range of complex and abstract ideas and should not be rushed. Although students may be able to use scientific terms correctly, it is important to question carefully to uncover the meaning students are attributing to these terms.

References

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[1] Steam and water vapour are commonly confused. Water vapour is water in its gaseous form. It is invisible. Steam is a mixture of water vapour and tiny droplets of liquid water.

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