

The conservation of matter and mass

Critical teaching ideas - Science Continuum F to 10

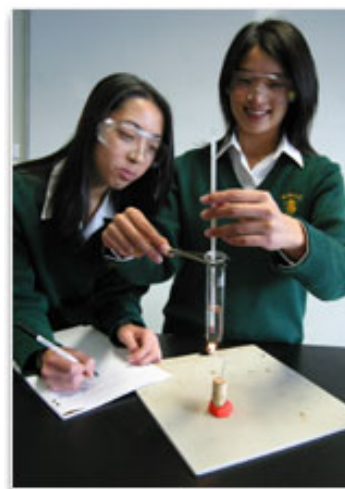
Level: Working towards level 10

Student everyday experiences

For many students the idea that matter is conserved is not a natural one. They observe sugar disappear when mixed with water, a large log burns “away” to a small amount of ash, cars rust and big holes appear, water boils away, frost and condensation appear from apparently nowhere, trees grow apparently from nothing but the soil.

Matter, it seems, disappears or appears during processes such as dissolving, burning, evaporation, boiling, rotting, respiration, rusting, condensation, and growth of plants. Invisible gases are involved in many of these processes leading to many of these alternative student conceptions. (See Driver, 1985; Russell Harlen & Watt, 1989).

Students often believe that matter is exchanged or converted into energy: wood turns into heat during combustion, food turns into energy when we metabolise it, or they confuse the energy of food (listed on packets as kilojoules) with the weight of the food. Students also often believe that the sun’s energy is changed into plant matter during the process of photosynthesis.



Students commonly believe that substances become lighter if they change into the gas state. If a liquid evaporates inside a sealed container then they believe that the combined weight of the container and the liquid will be reduced by the weight of the liquid because it has apparently disappeared. (See Stavy, 1990)

Although at this level the majority of students will have a strong understanding of the particle nature of atoms, for many, the numbers of atoms are not conserved during chemical reactions. They appear to grow in the bark of trees, and their numbers drop during processes such as combustion or decay and increase during photosynthesis.

The scientific view

- The idea of indivisible atoms helps to explain the conservation of matter. If the number of atoms stays the same no matter how they are rearranged, then their total weight stays the same.
- In all physical and chemical changes, the total number of atoms remains the same, hence when substances interact with one another, combine or break apart; the total weight of the system remains the same.

Growing plants get all of their new carbon (the great majority of their dried weight) from carbon dioxide i.e. from the air. When we lose weight by dieting or exercise, most of the loss is from breathing out the carbon atoms in our fat as carbon dioxide. When a liquid evaporates

in a sealed container, the weight stays the same; the gas particles are affected by gravity in the same way as tennis balls and they consequently hit the bottom surface of the container with more force than they hit the top.

Albert Einstein's prediction that mass can be converted into energy has been experimentally validated by numerous nuclear experiments. This implies that the statement that the "total weight of a system remains the same" is more correctly only a very good approximation for all non nuclear changes.

Critical teaching ideas

In physical and chemical changes:

- Particles just don't disappear or get created, rather their arrangements change.
- In any change involving matter, all of the matter must be accounted for. Matter does not turn into or appear from energy.
- Bits are rearranged to create a different substance from existing bits (integrity of particles).
- There is no change in weight when substances move in and out of the gas state.

In your teaching of conservation of matter and hence weight, students need to be encouraged to change their views from those based on their everyday experiences to more scientific views such as: there are only a fixed number of particles in the world and these building blocks are continually being rearranged into new things.

This is a difficult, abstract idea and we can use analogies to assist students with understanding. For example: 'It's a bit like having a bucket of Lego: you can build lots of different things but you only have a certain number of Lego pieces to do it with'. (See Loughran, Milroy, Berry, Gunstone & Mulhall, 2001). One of the difficulties is that closed systems involving change such as combustion and respiration are almost impossible to set up and weigh in a classroom. You can disprove by experiment only a few of the common alternative conceptions in this area.

It is important to discuss a variety of change situations that appear to involve non conservation of matter ideas and to revisit this in other topics such as ecosystems, food and diet, and sources of energy. Students should be encouraged to make predictions about these processes in a supportive classroom environment where they can be assisted to develop new theories, critically analyse their understandings and those of others, and compare these with scientific views presented by the teacher. It is easier to try to eliminate the alternative conceptions that can be experimentally tested first and have students then come to an understanding of the scientific model as one which can best explain a wide range of phenomena.

Reflection by students of how their views have altered will be a valuable component of achieving long lasting conceptual change in students and an understanding of the scientific explanations.

Teaching activities

Students should both discuss and observe phenomena where there is an apparent change in weight and be encouraged to seek alternative explanations.

Promote reflection on and clarification of existing ideas and to allow students to see how their ideas have changed.

A written probe of prior views: Ask students to write down and keep their views on a range of situations like the following: A fresh corpse is sealed in an airtight dungeon. 100 years later, the corpse is now a skeleton. Does the total weight of the dungeon, the corpse and other contents increase, decrease or remain unchanged? Where does the flesh go? Imagine a pile of fire wood burns in a sealed room. Does the total weight of the room and its products increase, decrease or stay the same? (See the tree growing in a box, below).

Open up discussion via a shared experience and promote reflection on and clarification of existing ideas.

POE (Predict, Observe, Explain) activities can be valuable in both eliciting student prior views and leading to reframing of these concepts. Ask students to predict what will happen when materials are burnt, weighing before and after, ensuring all products of combustion are retained (e.g. steel wool, magnesium). Note, that these experiments do not prove that the total weight is conserved in a closed system. In this case the system is open and the total weight of the steel wool /magnesium increased as they combine with oxygen from the air. What they do is show convincingly that weight is not always lost during combustion, and hence the notion of matter turning into heat is not sustainable. Similarly what happens in evaporation? Warm slowly a tightly stoppered flask containing 1 - 2ml of acetone. Students often predict the weight of the flask has decreased because gases are lighter than liquids, or the molecules are no longer sitting on the bottom.)

Promote reflection on and clarification of existing ideas.

Interpretive Discussions (where a teacher delays judging “incorrect” comments) can allow students to consider and reframe their views (after viewing the changes above and the many others that can be devised). For example, the acetone activity is very intriguing for students and can be used to revisit earlier, simple notions of how particles move in order to account for how they continue to exert a net downwards force.

Clarify and consolidate ideas for/by communication to others.

Poster making - small groups of students are given the opportunity to discuss their explanations and produce these as posters with diagrammatic explanations. Posters are then presented to the class.

Encourage students' to identify phenomena not explained by the (currently presented) scientific model or view.

Challenge the right answer - the teacher may formally present part of the scientific explanation and ask students to use this to generate further questions and explanations. For example, the combined weights of a small PET bottle, water and several antacid tablets is measured and recorded. The tablets are added to the water and the bottle quickly sealed and reweighed after the tablets have fully dissolved. The weight is unchanged yet the tablets have completely disappeared and gas generated. How can the weight remain unchanged?

Promote reflection on and clarification of existing ideas.

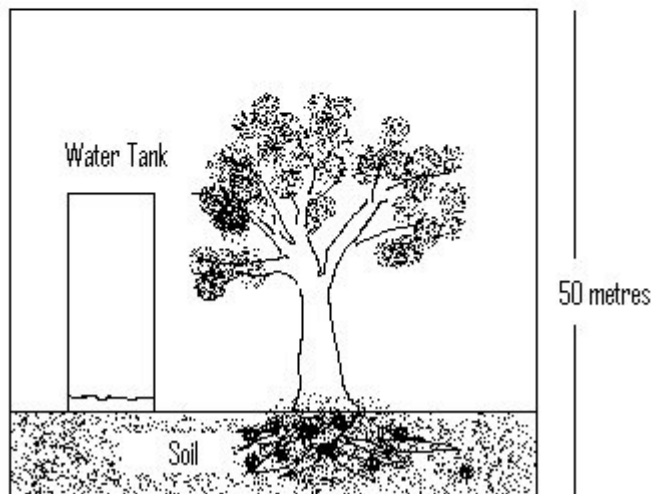
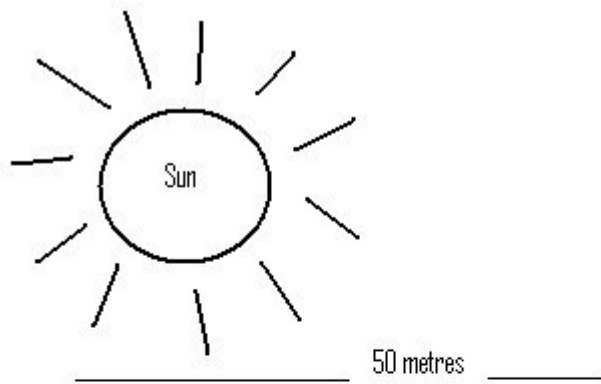
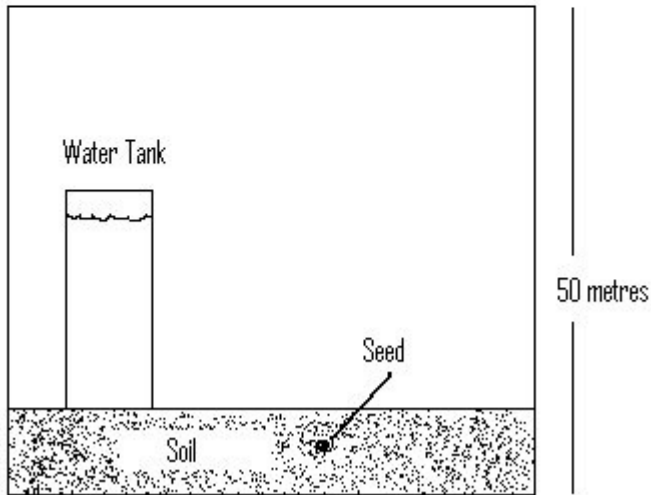
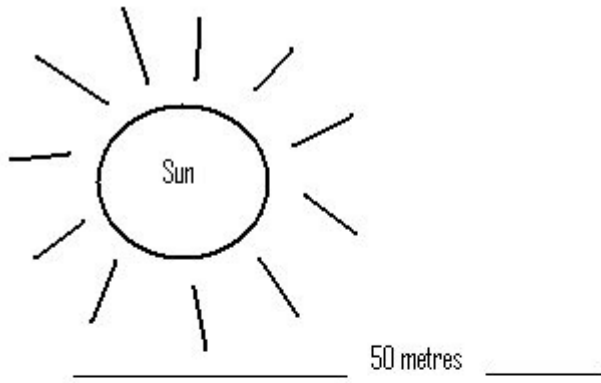
Testing theories - more problems can be presented e.g. .Inside a large sealed glass box, there is plenty of moist soil, a water tank with drip irrigation and the seed of a fast growing tree.

The box is placed in the sun for a year and a tree grows inside the box. The students are asked if the total weight of the box and the contents will increase, decrease remain unchanged during the years growth of the tree?

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:

- **Chemical Reactions: Combustion** – students investigate chemical reactions at a molecular level. They break apart molecules of oxygen and another substance into their component atoms and rearrange them to make molecules of new substances. For example, they explore how methane burns in oxygen to produce carbon dioxide and water. They also work out the number of molecules of each substance needed to balance the chemical equation
Learning Resource ID: HY5GUN



A further variation to consider is; without opening the box the tree is set on fire. After burning will the weight of the box change? What will happen to the number of atoms before and after both these changes?

Clarify and consolidate ideas for/by communication to others

Prior Warning of Poor learning Tendencies - ask students to consider the following situation: Your hand is full of carbon atoms; protein molecules are made up of C,H,O and N atoms. Consider one of these carbon atoms, let's call him Gilbert. Suppose that one million years ago Gilbert was in a blade of grass. Write a possible history of Gilbert over the last million years. In your answer refer to as many of the processes as you can. When you present this task, warn students they are likely to revert back to their prior views. (Very few students manage to write this essay without drawing on their prior views and writing things which are in conflict with everything they have just been taught). For students who return with essays showing very little knowledge of what they have just learnt, see if they can explain why they wrote the essays in this way even though they were warned.

Promote reflection on how students' ideas have changed

Returning to prior views - ask students to look again at their responses to the initial written probes of decay and combustion etc, and reflect on whether they changed their views. If they have ask them how they would change their answers to the situations and why they would change them. (Never mark their initial responses, but one can mark the reflective responses the second time around)

Students formulate their own hypotheses about weight changes in burning, respiration, photosynthesis and conduct investigations in order to prove or disprove them.