

Problems with classifying solids, liquids and gases

Critical teaching ideas - Science Continuum F to 10

Level: Working towards level 8

Student everyday experiences

Children's understandings of solids, liquids and gases have been well researched and confirm that their early conception of these terms is shaped by their everyday use of these words. Students are frequently reported as using the word "Solid" as an adjective rather than to mean a class of substances. (See Jones, 1984). Typically when students are asked for examples of each they are able to provide numerous examples of solids, less of liquids and only a few of gases which reflects their common experiences. Solids are typically identified as objects that can be held (See Krnel Watson & Glazar, 1998), Liquids as "dish washing liquids" that are "runny" or "wetting" and gases as LPG gas or propane gas that are combustible (See: A gas is matter). Everyday language appears to strongly influence early student identification. Eg. Solid steel, liquid detergent and camping gas are frequently provided when students are asked for examples of substances in each state.



Some students strongly believe that to be a solid the substance must be very hard and clearly consolidated into unbreakable lumps. Substances which appear as powders or in fine granules like sand or talc are often not identified as solids because they are viewed by children as easily shaped or freely poured. (See McGuigan Qualter & Schilling, 1993). Water and water based liquids eg milk, sea water, cordial, lemonade are reoccurring examples of liquids identified by children. Non water based liquids like cooking oils, kerosene, mineral turpentine; paraffin oil and oil based paints are less frequently identified. Evidence suggests that students freely associate liquids with water or assume they all contain some water because they are a liquid. (See Krnel Watson & Glazar, 1998).

The scientific view

The classification of matter into one of three states, solid, liquid or gas is a convenient way in lower levels for identifying when substances change state i.e. melt, boil, evaporate or freeze however because it is a simple system of classification and the structure of matter complex, it is not without difficulties. Many substances cannot be classified easily and many not at all. Eg Hair gel, toothpaste, mayonnaise, play dough and Oobleck (created from a mixture of corn starch and water) provide "fuzzy" examples which resist easy classification.

- Solids are best defined as occupying a constant volume and retain their shape when moderate forces are applied to them

- Liquids also occupy a constant volume but easily change shape to match that of their container by flowing to form a horizontal surface. They are said to “flow” easily or be “runny” or “wetting” and can withstand moderate compressive forces.
- A gas can occupy any size container, is also able to “flow” and can be easily compressed with moderate forces.
- A change in temperature can cause a substance to change state; however this may also be achieved by a change in pressure.

Students are often familiar with substances changing state during a temperature change, eg. Chocolate melting from the heat of their hand and molten candle wax freezing as it cools. Some substances like butter, are much more difficult to describe because they soften over a range of temperatures, compared with melting at a single melting point. Some substances formed from aggregates of atoms or molecules numbering from a few to a few hundred, can also coexist as solids and liquids over a range of temperatures and hence have distinctly different melting and freezing points, Gels, colloids, emulsions and many other substances defy simple classification because they contain mixtures of substances in different states over a range of temperatures.

Critical teaching ideas

- The purpose of classification is to identify objects with common or similar properties
- Solids, liquids and gases provide a simple means of classifying the state of matter but they are not the only groupings used by scientists.
- Some substances are very difficult to “classify”.
- Classifying states of matter has limitations but can still be useful.
- A change in temperature can cause a substance to change state.

When teaching about changes of state it is important to emphasise that although a substance has moved from one state to another i.e. melted from a solid to a liquid, it still remains the same substance. Students frequently believe that a change of state creates a new substance with entirely new properties. This is understandable given the obvious differences between the properties of the various states. The choice of teacher language during discussion is important in reassuring students that the substance remains the same although it appears to behave differently.

During class discussions encourage students to consider a wide range of suitable contexts which have strong connections to their everyday experiences. Consider examples of matter changing states based on drying clothes, melting butter and dripping icy poles. Look to extend student thinking beyond the common examples of water, ice water and water vapour. Discuss melting chocolate, candle wax, sugar and experiences that some children will have had with frozen carbon dioxide – dry ice.

Some observant students may question why we do not observe frozen carbon dioxide (dry ice) in a liquid state? Carbon dioxide change from a frozen solid (dry ice is solid below - 79°C) to a gas (called sublimation) without appearing to form pools of liquid. This is because it requires a pressure of approximately 60 times normal atmospheric pressure to remain in the liquid state. Students can consider that as it melts from a solid to a liquid it instantly boils to form a gas. Naphthalene (used to manufacture moth balls) is another substance which also sublimates at room temperature. (See Dry ice information from: <http://www.dryiceinfo.com/science.htm>).

Teaching activities

Practise using and build perceived usefulness of a scientific model or idea.

Provide small groups of students with a range of common objects (such as mixed buttons) composed of different substances and set them the challenge of devising a system of classifying them in ways which help to identify common features or properties. Their systems could be based on colour, hardness, whether they are natural, how they feel or how useful they are. It may be sufficient for students to be asked to identify just three common features for all items in the grouping. Students could draw up tables, or cut and paste images onto sheets to group them.

Careful consideration should be given to selecting items with obvious common properties for this task. Through class discussion, aim to promote the view that all of the features used to group the items are correct, however some groupings (systems of classifying) may be more helpful than others in identifying useful common features.



Open up discussion via shared experiences.

During class discussions encourage students to consider a wide range of suitable contexts which have strong connections to their everyday experiences. Consider scenarios for matter changing states such as drying clothes, melting butter and dripping icy poles. Aim to extend student thinking beyond the common examples of water, ice water and water vapour. Discuss melting chocolate, candle wax, sugar and experiences that some children will have had with frozen carbon dioxide (dry ice).

Use examples of dry ice and naphthalene in a Predict-Observe-Explain (POE) demonstration showing that some substances can change state from a solid to a gas without becoming a liquid. Investigate how students could detect that a gas is being released from both of these solid substances. Students can detect the naphthalene gas by smell. Spoon several dry ice pellets into an empty balloon and seal it by tying a knot in the neck. The balloon will inflate as the solid changes into a gas. Alternatively, drop dry ice pellets into a glass of water to see the production of gas bubbles. (Note that the fog produced is not carbon dioxide gas but tiny liquid droplets of water made visible by the cold gas mixing with moist air. This is a second change of state associated with this phenomenon).

Challenge students existing ideas.

Provide students with difficult to classify substances which challenge their definitions and force them to question their current understandings of the system of classification. At this level it is appropriate for students to see that some substances are more easily handled and don't require containers for them to be passed around (solids). Some substances are 'runny' and do require open containers for them to be handled (liquids) and some cannot be handled at all and require closed containers (gases). Once students have developed a strong understanding of this system of obvious classification they could be presented with substances which provide greater challenges, such as toothpaste, sand, hair gel, Ooblek or granulated sugar. Classifying these items will help to challenge the view that all substances can be easily classified.