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Ideas about Matter

Teaching Ideas with a Representational Focus

Written by Peter Hubber, Deakin University

These teaching notes were generated from an Australian Research Council (ARC) research project titled ‘The Role of Representation in Learning Science’ in which the topic of ‘ideas about matter’ was taught to Year 7 students in a Victorian state secondary school and Year 8 students at an Independent secondary school. A description of several of the activities that were undertaken is given as well as examples of the students’ work.

Ideas about Matter: Key Concepts and Alternative Conceptions

This section lists key ideas as well as alternative conceptions highlighted in the students’ conceptions research literature. This section also provides insight into Year 8 students’ pre-instructional thinking about this topic.

Key Concepts of Substances

Matter, substances and states of matter

- Objects are different to substances. Objects are made of substances. For example, an object like a desk is made of various substances, like wood, glue, metal and plastic.
- There are a huge variety of substances.
- A chemical is a substance that is either naturally occurring or manufactured by humans.
- Objects that take up space and have mass are called ‘matter’.
- All matter is composed of tiny indivisible particles too small to see even with the most powerful microscopes.
- There is nothing in the space between the particles that make up matter.
- Samples of substances can exist in one of three states: solid, liquid, gas.
- Most samples of substances can exist as a solid, liquid or gas, depending on the temperature of the substance.
- The temperature of a substance is related to the average kinetic energy (motion energy) of the particles that make up the substance.
  - The particles are in constant motion in all physical states.
  - Particles in a solid vibrate about a fixed position and are relatively close together.
  - Particles in a liquid move more freely, have no fixed position, and are still relatively close together.
  - Particles in a gas are moving freely, have no fixed position, and are far apart.
  - The lowest temperature possible for a substance is -273° C.
- Substances can have a range of physical properties, including colour, density, electrical conductivity, hardness and flexibility.
  - Liquids differ in a range of properties, including viscosity (runniness), density and transparency.
  - Liquids do not compress.
- The particles that make up the substances do not share the properties of the substance they make up. For example, when wax melts the particles do not change from firm to being soft.
Ideas about Matter Teaching Notes, Peter Hubber, Deakin University

- Particles are similar in size and their sizes do not change when the substance changes temperature or changes state.
- There are forces of attraction holding particles together in a solid and liquid.

**Physical changes**

- In a physical change the nature of the substance, the particles of which it is composed and the numbers of particles remain unchanged.
- Equal volumes of different substances usually have different masses.
- A substance undergoing a change of state is undergoing a physical change.
- Chemical reactions involve the production of new materials which are quite different from the reacting substances. Any new materials come from the reacting substances.
- 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.
- When substances dissolve in a liquid, their molecules intersperse amongst those of the liquid.
  - Different substances will dissolve in different liquids.

**Atoms and molecules**

- Matter consists of tiny particles called ‘atoms’, which are far too small to see directly through a microscope.
- Atoms may stick, or bond, together in well-defined molecules, or may be packed together in large arrays, or lattice structures. Different arrangements of atoms compose all substances.
- In physical and chemical changes the number of atoms stays the same no matter how the same atoms are rearranged.
- Atoms and molecules are perpetually in motion. Increased temperature means greater average kinetic energy, so most substances expand when heated.
- In solids, the atoms or molecules are closely locked in position and can only vibrate. In liquids, they have higher energies, are more loosely connected, and can slide past one another; some molecules may get enough energy to escape into a gas. In gases, the atoms or molecules have still more energy and are free from one another except during occasional collisions.
- Atoms and combinations of atoms can be represented by symbols and formulae.

**Alternative Conceptions of Ideas about Matter**

The following list of non-scientific ideas has been cited by the research literature into students’ (and teachers’) understanding of astronomical phenomena. The research literature prefers the use of the term *alternative conception* rather than *misconception* as it recognises the often strongly held view by the student; they feel such views make more sense to them based on their prior experiences.

**Matter, substances and states of matter**

- Matter is continuous, but contains particles.
  - The space between atoms and molecules is filled with air.
  - There is no space between molecules in solid objects.
- Substances and atoms are different names for the same things.
- Objects and substances can mean the same thing.
- There are more than three kinds of ‘stuff’; e.g. solid, liquid, powder, paste, jelly, slime, paper-like, etc.
- Matter can disappear
  - When matter disappears from sight (e.g. dissolving, evaporating) it ceases to exist.
Matter is not conserved in evaporation: “Gas weighs less than liquid”.
• Solute (salt, sugar) disappears when dissolved.
• The wax from a burning candle disappears.
• Matter can disappear, and its properties (sweetness, smell, etc.) can continue to exist completely without it.
• Matter can have no or negative mass.
  • Air has no mass.
  • Air has negative mass.
• A chemical is a substance that has been man-made.
• Odour or smell of a substance is quite separate to the particles that make up the substance.

Physical changes
• The mass of a substance does not remain constant during a physical change.
  • A sealed container with a bit of liquid in it weighs more than after the liquid has evaporated.
  • The mass of a substance changes as it melts or evaporates.
  • The mass of a substance changes when it dissolves.
• Substances disappear during a physical change.
  • Water disappears as it evaporates.
  • Sugar disappears when dissolved in water.
• Substances in different states are not considered to be the same substance.
  • Vapour is something different from water.
  • Water from melting ice is different from running water.
  • Sugar left after water has evaporated is not the same sugar that was dissolved in the water.
• Bubbles from boiling water consist of:
  • air or
  • air and oxygen gas, or
  • hydrogen gas, or
  • heat.
• Boiling water becomes smoke.
• The temperature at which water boils is the maximum temperature to which it can be raised.
• There is no limit to the lowest temperature.
• Drops of water on the outside of a cold bottle of water:
  • comes from inside the bottle.
  • drops of water on the outside of a bottle are made by the cold.
• Melting and dissolving are the same thing.
  • Salt becomes liquid salt when it dissolves.
  • Dissolving sugar becomes melted.
• Freezing is like drying.
• Heating a substance always means raising the temperature even through a phase change.

Atoms and molecules
• Atoms can be seen with a (electron) microscope.
  • Size of atoms/molecules is greatly overestimated.
• Atoms are like cells with a membrane and nucleus.
Atoms can reproduce after the nuclei divide.

- Atoms/molecules have the properties of the bulk material they constitute. For example, solid chocolate has hard atoms, melting chocolate has soft atoms.
  - Gold atoms are gold in colour.
- Atoms are:
  - hard, like billiard balls.
  - soft and fuzzy.
  - like building blocks.
- Atoms/molecules change properties in different states.
  - Atoms/molecules expand when heated.
  - Atoms/molecules of solids are hard, molecules of gases are soft.
  - Atoms/molecules of solids are biggest, molecules of gases are smallest.
  - Atoms/molecules of solids are cubes, molecules of gases are round.
- Mass is conserved but not the number or species of atoms.
- There is only one correct model of the atom.

**Year 8 students’ ideas about matter**

The students were in Year 8 and had undertaken a topic about ‘matter and particle model’ in their previous year. Despite this, many of the students still exhibited alternative conceptions as they relate to this topic on the pre-test (Appendix 2). This led to the adoption of several activities that challenged the students’ Alternative Conceptions.

**Q1 pre-test responses**

The students were asked to construct sentences which gave meaning to the terms ‘chemical’, ‘substance’ and ‘molecule’. Few students could provide a statement indicating a scientific meaning.

- For the term ‘chemical’ some students held the view that chemicals are non-natural substances, others pointed to a key characteristic that it must be a liquid and/or a substance that reacts or is a mixture. Examples of student responses:
  - A chemical is a mixture of substance.
  - A chemical is man-made.
  - A chemical something that mixes within another chemical to cause a reaction.
- For the term ‘substance’ there was an association between a substance and the three states of matter, something/material/object or a mixture. Examples of student responses:
  - A substance is a solid, liquid or gas.
  - A substance is something like matter.
  - A substance is normally a mixture.
- For the term ‘molecule’ most students believed they are particles that make up matter; very few made an association with atoms. Some viewed molecules as the constituents of all matter. Examples of student responses:
  - A molecule is a building block of everything.
  - A tiny particle that has one or more atoms joined together
  - A small particle that makes up a chemical or a substance.

**Q2 pre-test responses**

The students were to classify the state of certain items, which were either pure substances or mixtures of substances; a term instead of ‘item’ could be ‘stuff’ so that a sample of stuff is either a pure substance or mixture. **Table 1** shows the students’ responses:

- Many view a difference as to the state of chalk when in stick form compared to powder form.
• Large variations in classifying toothpaste, whipped cream, dust cloud and honey.

• Most students believed that propane is in a gas state in the bottle. This is understandable given that everyday language supports the view that ‘propane is a gas’.

Table 1 Year 8 students’ pre-test responses to Q2

<table>
<thead>
<tr>
<th>Item</th>
<th>Solid</th>
<th>Liquid</th>
<th>Gas</th>
<th>Mixture</th>
<th>Unsure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chalk powder</td>
<td>55%</td>
<td>0%</td>
<td>0%</td>
<td>14%</td>
<td>31%</td>
</tr>
<tr>
<td>Chalk stick</td>
<td>98%</td>
<td>0%</td>
<td>0%</td>
<td>2%</td>
<td>0%</td>
</tr>
<tr>
<td>Toothpaste</td>
<td>0%</td>
<td>24%</td>
<td>0%</td>
<td>71%</td>
<td>5%</td>
</tr>
<tr>
<td>Smoke</td>
<td>91%</td>
<td>0%</td>
<td>0%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>Sponge</td>
<td>86%</td>
<td>0%</td>
<td>0%</td>
<td>9%</td>
<td>5%</td>
</tr>
<tr>
<td>Dust Cloud</td>
<td>0%</td>
<td>0%</td>
<td>63%</td>
<td>23%</td>
<td>14%</td>
</tr>
<tr>
<td>Whipped Cream</td>
<td>0%</td>
<td>18%</td>
<td>0%</td>
<td>76%</td>
<td>6%</td>
</tr>
<tr>
<td>Propane in the bottle</td>
<td>0%</td>
<td>14%</td>
<td>80%</td>
<td>0%</td>
<td>7%</td>
</tr>
<tr>
<td>Honey</td>
<td>0%</td>
<td>78%</td>
<td>0%</td>
<td>22%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Q3 pre-test responses

The students were asked which of a set of items contained molecules. Table 2 shows the students’ response to this question indicates a lack of understanding that items except lightning and sunshine all contain molecules.

Table 2 Year 8 students’ pre-test responses to Q3

<table>
<thead>
<tr>
<th>Item</th>
<th>% who believe the item contains molecules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunshine</td>
<td>30%</td>
</tr>
<tr>
<td>Air</td>
<td>53%</td>
</tr>
<tr>
<td>Soil</td>
<td>67%</td>
</tr>
<tr>
<td>A Frog</td>
<td>63%</td>
</tr>
<tr>
<td>Salt</td>
<td>60%</td>
</tr>
<tr>
<td>Lava</td>
<td>83%</td>
</tr>
<tr>
<td>Lightning</td>
<td>30%</td>
</tr>
<tr>
<td>Sea water</td>
<td>77%</td>
</tr>
<tr>
<td>A mars bar</td>
<td>57%</td>
</tr>
</tbody>
</table>

Q4 pre-test responses

The students were asked to determine the mass of a system of items that included a beaker, water and a sugar cube before and after the sugar was dissolved. Nearly all the students correctly responded to this question showing an understanding of conservation of mass when substances dissolve. In the written explanation many of the students used the term ‘dissolve’ and added comments to provide scientific meaning to this term. For example,

- The sugar dissolved. The water broke it down into particles that are floating around but we cannot see.
- It was dissolved into the water. Its particles were broken up by the water and spread out so it could not be seen.

Q5 pre-test responses

The students were asked if one could compress a syringe (needle removed) if it contained air or water. Air with syringe: 35% of the students believed the plunger would not move with only a handful of students suggesting the plunger would move a small amount.

- You would not be able to push the plunger down because the air inside can’t move out of the end.
- You can push the plunger in a certain amount because air has less particles than other substances.
Water with syringe: 30% of the students suggested the result with water would be the same as with the air. The rest believe the plunger would not move.

- *The same thing would happen, the water is compressed but cannot leave so the plunger will not move.*
- *The water will not move it is in its densest state and you could not compress it.*

**Q6 pre-test responses**

The students were asked to show diagrammatic representations of what they imagine is happening on a super-magnified scale before and after wax melting. Most students produced representations of particles of wax as either circles or dots.

<table>
<thead>
<tr>
<th>Solid Wax</th>
<th>Liquid Wax</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Solid Wax" /></td>
<td><img src="image" alt="Liquid Wax" /></td>
</tr>
</tbody>
</table>

Typical representation – ordered stacking of particles shown as circles or dots which are close together

Typical representation – disorder of particles shown as circles or dots and further apart than that shown in the solid.

In commenting about solid wax several students argued that because the particles are closely packed they cannot move. Many students made a written comment that the particles in the liquid are moving further apart. Some refer to the particles ‘melting’ or ‘expanding’ thus invoking macroscopic properties to the particles.

Whilst the students write about the particles being connected and moving, none of them (except one student with a side diagram) represented this in anyway. It would appear to be the standard textbook (iconic) representation that the students believed they should be drawing.

**Q7 pre-test responses**

The students were asked to respond to the truthfulness, or otherwise, about a set of statements related to Ideas about Matter. **Table 3** shows the student responses and indicates:

- Few students were unable to respond that they didn’t understand the statement.
- Most students had an understanding of the terms ‘chemical’ [statement A], ‘atom’ [B], ‘molecule’ [C] & ‘condensation’ [J].
- Many students didn’t apply the key ideas that underpin the particle model to explain macroscopic behaviour of matter.
  - Atoms can be seen with microscopes [D]
  - Atoms/molecules have the properties of the bulk material they constitute [H]
  - Smell is disassociated with particles [I]
  - Mass is not conserved in changes of states of matter [K]
  - Atoms/molecules/particles of matter in solid state are stationary [L]
  - Matter is continuous and contains particles [N]
- Many students don’t apply key ideas associated with substances and changes of states of matter.
  - Oxygen can only be a gas [E]
  - Temperatures less that -273 °C are possible [G]
Table 3 Year 8 students’ pre-test responses to Q5

<table>
<thead>
<tr>
<th>Statement</th>
<th>True</th>
<th>False</th>
<th>I Don’t Understand</th>
<th>Not Sure</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. A chemical is always a substance that is man-made.</td>
<td>19%</td>
<td>64%</td>
<td>7%</td>
<td>10%</td>
</tr>
<tr>
<td>B. All objects consist of very tiny particles called atoms.</td>
<td>78%</td>
<td>8%</td>
<td>0%</td>
<td>14%</td>
</tr>
<tr>
<td>C. A molecule is a tiny particle that consists of more than one atom bonded to each other.</td>
<td>64%</td>
<td>2%</td>
<td>5%</td>
<td>29%</td>
</tr>
<tr>
<td>D. Even with the most powerful of microscopes scientists have still not been able to see the atoms.</td>
<td>21%</td>
<td>45%</td>
<td>2%</td>
<td>31%</td>
</tr>
<tr>
<td>E. Oxygen is substance that is always a gas.</td>
<td>49%</td>
<td>41%</td>
<td>0%</td>
<td>10%</td>
</tr>
<tr>
<td>F. When a substance freezes the temperature must always be less than 0 °C.</td>
<td>40%</td>
<td>52%</td>
<td>0%</td>
<td>7%</td>
</tr>
<tr>
<td>G. It is possible to heat an object to +1000 °C but it is not possible to cool it -1000 °C.</td>
<td>40%</td>
<td>31%</td>
<td>2%</td>
<td>26%</td>
</tr>
<tr>
<td>H. When wax melts the molecules that make up the wax change from being hard and firm to being soft and ‘gooey’.</td>
<td>76%</td>
<td>11%</td>
<td>8%</td>
<td>5%</td>
</tr>
<tr>
<td>I. To be able detect the smell of chocolate molecules of the chocolate need to go up your nose.</td>
<td>45%</td>
<td>31%</td>
<td>5%</td>
<td>19%</td>
</tr>
<tr>
<td>J. When a substance condenses it changes from a gas into a liquid.</td>
<td>71%</td>
<td>12%</td>
<td>2%</td>
<td>15%</td>
</tr>
<tr>
<td>K. A closed bottle with small amount of water at the bottom is left in the sun. After awhile, when the water has evaporated, the mass of the bottle is now less than before.</td>
<td>43%</td>
<td>48%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>L. The molecules inside liquids and gases are moving but in solids they are stationary.</td>
<td>71%</td>
<td>19%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>M. The bubbles that are created when water boils are made of either Air, or Hydrogen and Oxygen.</td>
<td>61%</td>
<td>12%</td>
<td>7%</td>
<td>20%</td>
</tr>
<tr>
<td>N. In the spaces between atoms of an object there is air.</td>
<td>14%</td>
<td>38%</td>
<td>7%</td>
<td>40%</td>
</tr>
</tbody>
</table>

Q8 pre-test responses

The students were expected to read from a Temperature Time graph and interpret a section of it that represented the melting of wax. 92% of the students could read the graph to determine the temperature of the wax after 6 minutes of heating. Most could not explain the significance of the flat section of the graph from a scientific perspective. They suggested experimental error or heating was interrupted. However, A few students correctly indicated that this was the point at which the wax melted.

Q9 pre-test responses

The students were asked to imagine they were a perfume particle in a closed bottle and the top to the bottle is removed.

In the student responses there was a good sense that the particles of perfume cover all areas of the room. There was a common view that the particles are lighter than air and so float out of the bottle. There were several students who didn’t consider adding a drawing. The third student example below is interesting for the multi-representational modes used in explaining what happens.

- You would be constantly moving around so if the lid is left open you would bounce off the walls of the bottle until you moved in the direction of the exit.
- Because the perfume is compact in a bottle it is a liquid but when exposed to air the perfume can easily float away.
Ideas for teaching Ideas about Matter

Pedagogy underpinning the Teaching and Learning of Topic Sequence

The pedagogy associated with teaching this curriculum is outlined in Appendix 1. The key concepts that underpin any topic in science are understood from a multiple representational perspective and so learning science becomes a representational challenge for the teacher as well as the student.

Introduction to Ideas about Matter

The introductory activities should focus on exploring what understandings students bring to this topic. Activities include a pre-test, class discussion and classification activities.

Pre-test Questionnaire

Key Ideas

- Understanding of many key ideas are being tested.

Description of Activity

Administer the questionnaire (refer to Appendix 2) to the students: My current ideas about what makes up the things about me. Emphasis should be placed on what the students currently know about what makes up the objects about us and so use of the term test should be avoided.

Teacher Notes

The results of the questionnaire will give some insight into the students’ pre-instructional ideas about matter and will inform the types of activities to be undertaken. This was certainly the cases in for students in both the Year 7 and Year 8 classes where a variety of alternative conceptions surfaced. For example, there was a belief that air in a syringe could not be compressed so students were given the opportunity to test this out in the lesson sequence.

Some terminology to agree upon

Key ideas

- **Objects** that take up space and have mass (or weight) are called **matter**. Examples of objects are: desk, body, cloud.

- **Substance** is defined as **matter** of definite composition and properties. **Objects** are different to **substances** in that **objects** are made of **substances**. For example, an **object** like a desk is made of various, like wood, glue, metal (iron) and plastic.

- You cannot just have a **substance** – you need to have an amount of it, which we call a **sample**. **Samples** of **substances** can be in any of three states – solid, liquid gas. A **sample** of the **substance**, water can be in a solid (ice), liquid (water) or gas state (water vapour).
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- A **chemical** is a **substance** that is either naturally occurring or manufactured by humans; in other words, a **chemical** can be any **substance**. For example, water is a chemical.

**Description of Activity**

Make reference to the students’ responses in the pre-test as it relates to what their understanding of the terms **chemical** and a **substance**; that is, give a summary of what the students wrote. Give recognition to the everyday language use of the word chemical as:

- A man-made substance
- Ingredients for a chemical reaction.

Also explore other words students associate with these terms, for example, materials, natural things, organic products. Emphasise the point that scientists use words with very specific meanings which sometimes conflict with meanings associated with the everyday meanings. This is the case with **chemical** where scientists have an expanded meaning of chemical to include all substances. The terms **chemical** and **substance** and be used interchangeably.

Establish the terminology of **matter**, **substance**, **objects** and **sample**. A discussion about this terminology might include an exploration of objects in the room. Ask the students to list some objects that are in the room – what substances are they made of? What state are the samples of the substances in the object at the temperature of the room? To reinforce these terms consider the following class/student activity:

**Objects in the room**

Ask the students to list 5 objects that are in the room – what substances are they made of? What state are the samples of the substances in the object at the temperature of the room? Draw up a table (some example objects are given). Emphasise that the state of the substance sample is connected very much with its temperature. So when we talk about the state of a particular sample of a substance it is always at a specific temperature which needs to be stated. There is an exception here in that a gas that exist at a certain temperature can also exist as a liquid at that temperature if compressed.

<table>
<thead>
<tr>
<th>Object</th>
<th>Substance/Chemical</th>
<th>State of sample of substance (21 °C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eraser</td>
<td>Rubber</td>
<td>Solid</td>
</tr>
<tr>
<td>Pen</td>
<td>Plastic</td>
<td>Solid</td>
</tr>
<tr>
<td></td>
<td>Ink</td>
<td>Liquid</td>
</tr>
<tr>
<td></td>
<td>Metal (steel)</td>
<td>Solid</td>
</tr>
<tr>
<td>Air</td>
<td>Oxygen</td>
<td>Gas</td>
</tr>
<tr>
<td></td>
<td>Nitrogen</td>
<td>Gas</td>
</tr>
<tr>
<td></td>
<td>Carbon Dioxide</td>
<td>Gas</td>
</tr>
</tbody>
</table>

Emphasise that a substance is not in any particular state, only a sample of the substance is in a state (solid, liquid, gas). For example, referring back to the Year 8 pre-test all but a few students said that the sample of propane [we use this gas to light up the BBQ] in the bottle was a gas, when it is in a liquid state [under pressure]. Also, most students suggested that the statement **Oxygen is substance that is always a gas** was true. Student might also have heard the term LPG which stands for Liquid Petroleum Gas that some cars can use instead of petrol. Students’ alternative conceptions that substances like **Nitrogen** or **Carbon Dioxide** are gases can be physically challenged with either or both of the following demonstrations:

**Exploring Carbon Dioxide and Nitrogen**

You will require a sample of dry ice and/or liquid nitrogen. Open up discussion about what the students know about the substances called carbon dioxide or nitrogen. Common views include:

- Carbon dioxide is a greenhouse gas
- Nitrogen is a major component of air (78%).
Everyday language supports the view that these substances are gases. This view can be challenged with a sample of solid carbon dioxide (the fire extinguisher in the room has a sample in a liquid state) and liquid nitrogen. Why don’t we normally see samples of carbon dioxide or nitrogen in other states than as gases?

Some activities that can be shown to the students include:

- **CO₂**
  - Place some dry ice in a beaker and add some warm water – sublimation of CO₂ changing from a solid to a gas occurs very quickly with great white plumes of CO₂ forming.
  - Place some dry ice into a balloon and observe changes to the balloon over a period of time. The balloon expands – ask the students to explain why.
  - Place some dry ice around the base of a lit candle. Soon the candle goes out.

- **N₂**
  - Dip one end of a rubber-tubing into the liquid nitrogen – with a hammer one can shatter the cooled end.
  - Place a banana or a flower into the liquid nitrogen – observe the changing property of these objects in terms of becoming very brittle.

**Classroom example**

It was only the Year 7 class that experienced the demonstration of the dry ice and liquid Nitrogen. Apart from highly engaging the students they realised that carbon dioxide and nitrogen are not gases, only samples of them are at certain temperatures.

**Teacher Notes**

The Year 8 and Year 7 pre-test data provided mixed understandings of some key terms such as chemical and substance. For example, a chemical was regarded as a non-natural substance (synthetic substance) or something that you mix with something else to make a chemical reaction (a reactant). A substance was often described as a solid, liquid or gas (a state of matter). Therefore, any initial discussions need to have students using the same meanings as the teacher.

The discussion of the terms explores the different representational modes of scientific and everyday language.

A discussion about carbon dioxide may very well lead to the current environmental issue of global warming and its relationship to the greenhouse effect.

**Exploring the words chemistry and chemists**

Other words to explore with students are chemistry and chemists. Students at junior levels like being told they are engaging in one of the key domains of science.

Open up a discussion with the students: What is chemistry? What to chemists (chemistry scientists) do?

In this topic students will be investigating the properties of different substances and working out how they have these properties. For example, why is chalk so brittle (breaks when you try to bend it) and yet rubber is elastic (able to be bent or stretched).

**Teachers Notes**

Two aspects that make up the heart of chemistry are:

- Chemistry is about making forms of matter that never existed before. From plastics and detergents to swine flu vaccines and anticancer drugs, new materials have had an extraordinary impact on our lives.
- Chemistry is about analysing substances and working out how chemical reactions happen. This has allowed us to control industrial processes, monitor our environment and assess our health needs.

Chemists are very interested in exploring the properties of materials so as to enhance their use for society. Once the properties of a material are known they can be considered as replacement materials or even used to make new products for use by society. For example, plastic bags are now commonly used in supermarkets to replace paper bags.

An understanding of the electrical properties of silicon (found in common sand) has led to the revolution in computer technology. New materials are being produced by chemistry on a regular basis and will eventually find their way into our daily lives (if they have not already done so). Some common new materials include
Teflon, Kevlar and graphite fibre. How often do we hear on news bulletins about the release of a new medicine that claims to assist in the treatment of such diseases as cancer or AIDS?

Manufactured or artificial substances are quite often referred to in everyday speech as ‘chemicals’. There are even notions that chemicals can be dangerous for us; there are debates about food products that are grown with pesticides or growth enhancers in contrast to so-called ‘organic’ products that are grown without the addition of these synthetic materials. The use of the term ‘chemical’ for a synthetic material is incorrect from a scientific perspective. Everything is made up of chemicals whether humans had some involvement in its production or not. An organically grown apple contains chemicals as does one grown with the use of pesticides (however, the mix of chemicals may be different).

**How many ways can we group matter?**

**Key Ideas**

- Studying similarities and differences in the properties of substances is one important aspect of Chemistry and the role of chemical scientists.
- Chemists often categorise matter in various ways depending on the properties of the matter. For example,
  - Solids, liquids, gases.
  - Acids, bases
  - Metals, non-metals
  - Conductors, insulators
  - Organic and inorganic compounds

**Description of Activity**

You might open up discussion that chemists often classify matter in terms of their properties. This activity is for the students to construct their own categories.

Handout the images of various substances (Appendix 4) to each student; they are to then form pairs. Each pair is to cut each image and then to classify them into different groups; they are to construct two different classification systems. They decide on the groupings. They are to present their classification system in their workbooks clearly labelling their groupings.

In presenting their categories they might like to explore different representational modes. For example, tables, Venn Diagram or a continuum.

After the students have constructed both their classification systems discuss with them their groups and descriptions of each.

**Teacher notes:**

The representations students use to show their classifications might vary from tabular form to Venn Diagram (this representation might be useful for items that are considered by students to fit into two different categories). Most of the Year 7 & 8 student groups chose as one of their classification systems related to states of matter.

Normally a sample changes state at different temperatures but in the case of propane (one of the items on the images sheet) it has a boiling point of −42 °C but in the gas bottle it’s temperature is much higher (say 20 °C). In this instance the propane remains in a liquid state due to pressure – release the pressure and a change of state occurs.

**Exploring Properties of Matter**

**Exploring substances – what do we observe?**

**Key Ideas**

- Studying similarities and differences in the properties of samples of substances is an important aspect of Chemistry and the role of chemical scientists.
- Samples of substances are identified by the properties they have.
**Description of Activity**

Open up a discussion as to what words the students could use to describe the properties of objects. One could give two for the students to analyse – sheet of absorbent paper, plastic shopping bag. For the absorbent paper the substance is wood so the students are analysing a sample of wood; for the bag the substance is plastic.

Some examples of properties of these samples:

<table>
<thead>
<tr>
<th>Sample of wood</th>
<th>Sample of plastic</th>
</tr>
</thead>
<tbody>
<tr>
<td>White in colour</td>
<td>White in colour</td>
</tr>
<tr>
<td>Can bend it (flexible)</td>
<td>Can bend it (flexible)</td>
</tr>
<tr>
<td>Can absorb water</td>
<td>Can stretch it and it springs back into shape (elastic)</td>
</tr>
<tr>
<td>Made up of fibres stuck together</td>
<td>Can overstetch it but still not break</td>
</tr>
<tr>
<td>Can’t be stretched</td>
<td>When picked up holds its shape</td>
</tr>
<tr>
<td>When picked up it holds its shape</td>
<td></td>
</tr>
</tbody>
</table>

Students are given various objects to analyse in terms of their properties – maybe a round robin format where students might go to three stations or just the one station where each group gets a mix of three samples of stuff to analyse.

Things to analyse might include everyday stuff and some interesting stuff:

- Rubber band
- Toothpaste
- Shaving cream
- Paper clip
- Cornflour and water mixture
- Slime
- 100s and 1000s (in a beaker)
- Peanut butter (crunchy kind)
- Aluminium foil

**Properties of common objects**

**Key ideas**

- Samples of substances in a solid state have a fixed shape and volume
- Samples of substances in a solid state can have a range of properties

**Description of Activity**

Present the students with the following set of paired images either bangle/rubber band or honeycomb/flake.

The students are to answer the following questions:
- What are the objects here?
- What are the substances that they are made of?
- What properties does each have in common?
- What properties do each have that distinguishes it from the other object?

The student could present their answers using a Venn Diagram.
Properties of states of matter

Key Ideas

- Most samples of pure substances can be in one of three states; solid, liquid and gas.
- A sample of substance may change state with a change in temperature.
- Samples of a substance in
  - A solid state have a fixed shape. It has a fixed volume and it is not compressible.
  - A liquid state doesn’t have a fixed shape and are able to change their shape by flowing. It has a fixed volume and is not compressible.
  - A gas state has no definite shape or volume and can be compressed. If unconstrained a sample in a gas state will spread out indefinitely. If confined they will take the shape of their container.

Description of Activity

Get the students to consider two different representations for solids, liquids and gases. These are:

1. Continuum representation.
2. Venn diagram representation.

Continuum representation

Brainstorm with the students samples of substances that can be found at home; alternatively, give them a list. It might be useful to think about solids, liquids and gases as a sort of continuum (like a number line) and not as separate distinct categories. As an activity students could put items somewhere along this continuum. For example, this is for items at room temperature (should be noted)

<table>
<thead>
<tr>
<th>SOLID</th>
<th>LIQUID</th>
<th>GAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spoon</td>
<td>Crunchy Peanut Butter</td>
<td>Milk</td>
</tr>
<tr>
<td></td>
<td>Smooth Peanut Butter</td>
<td>Shaving cream</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Air</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Milkshake</td>
</tr>
</tbody>
</table>

Venn diagram representation

Brainstorm properties of solids, liquids and gases. Place items from this list into a Venn Diagram. A discussion about what should be put into each section can be made with the students. Alternatively, like the continuum, students can place substances into the various sections. For example, a mixture like toothpaste would be in section 4. Can the students think of a substance for each section of the Venn Diagram?

<table>
<thead>
<tr>
<th>Section</th>
<th>Labels</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Can be poured out of one container into another</td>
</tr>
<tr>
<td>2</td>
<td>Fixed shape</td>
</tr>
</tbody>
</table>
Can be compressed  
Spreads out to all parts of the container

Fixed volume  
Can’t be compressed

Carbon Dioxide changes directly from a solid to a gas when heated.

Spreads out if not in a container

Same material whatever the state

A Venn diagram will assist the students in understanding the similarities and differences between the different states of matter.

<table>
<thead>
<tr>
<th>Liquid State</th>
<th>Solid State</th>
<th>Gas State</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>1</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Teacher’s Notes:
This Venn diagram can be revisited when particle ideas are discussed. They should draw the particle ideas in a different colour to differentiate the macro (what we observe) and micro (what we imagine). Some examples of categories in the various sections are:

<table>
<thead>
<tr>
<th>Section</th>
<th>Labels</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Particles move around each other</td>
</tr>
<tr>
<td>2</td>
<td>Particles vibrate around fixed positions</td>
</tr>
<tr>
<td>3</td>
<td>Particles are not bonded</td>
</tr>
<tr>
<td>4</td>
<td>Particles are connected – they have bonds</td>
</tr>
</tbody>
</table>
| 5       | Sublimation (change from solid to gas state – dry ice heated)  
Deposition (change from a gas to a solid state - formation of snowflakes) |
| 6       | Boiling  
Condensation |
| 7       | Matter is made of particles  
Particles are moving  
There is space between the particles |

At this stage students should only consider the properties without considering particles ideas.  
In terms of states of matter there are four states – the fourth one, plasma, on a microscopic level is matter mostly stripped of electrons creating an ionised gas. Flame, lightning, interstellar nebulae and stars are
examples of the plasma state of matter. It’s not important to bring this up although some students might have heard the term.

It should be pointed out that samples of all substance can’t always exist in any state no matter what the temperature. For example, dry ice (carbon dioxide) and diamond (carbon) don’t exist in a liquid state – when heated each changes from a solid to a liquid state – the change of state is called sublimation.

Deciding on weather a sample is a solid, liquid or gas might be a bit tricky sometimes. For example, the sample of stuff might be a mixture of substances in different states [toothpaste is a mixture of samples in a liquid (water) and solid (small abrasive bits) form]

Refer back to the items that were investigated in the previous activity. Make a list of key characteristics of a liquid, solid and gas in line with the key ideas made above. However, these characteristics can sometimes be questionable for some objects. For example,

- Point out the difficulties with the definition for a liquid that one can pour is from one container to another when considering fine sand or 100s and 1000s. Even though the sand is in small bits each bit holds its shape so must be considered a solid.
- Stuff like toothpaste and peanut butter are pastes so some discussion about pastes needs to take place as to whether these are liquid or solid or somewhere in-between. Incidentally toothpaste and peanut butter are mixtures – if you leave them out in the sun they go hard as the liquid evaporates leaving the solid.
- The cornflour/water mixture, called Oobleck, is a strange mixture as it sometimes acts like a liquid and sometimes acts like a solid. For example, if you place a spatula into the mixture and stir slowly it will act like a liquid but if stir quickly the mixture resists very hard, like a solid would. There are utube videos of people who can walk on this mixture if they stomp very hard but if the walk lightly they sink very easily [I can get the video if you are interested in showing this to the students].

Compressing states of matter (Predict Observe Explain [POE] strategy)

Key Ideas

- A sample of a substance in a solid and liquid state do not compress (need to make the point that a sample of foam is a mixture of states so if the air pockets were filled with air in a solid state then the foam would not compress)
- Samples of a substance in a gas state do compress.

Description of Activity

In the pre-test many of the Year 7 and 8 students had the alternative conception that air does not compress. This view can be directly challenged with the following done either by the students or done by the teacher as a demonstration.

Equipment

- Large syringe (like that shown below) without the needle.

Make reference to the pre-test question response in terms of giving the students an indication of the popularity of each different view – one could either read out specific responses or invite responses from the class.

Syringe image Source: retrieved Jun 5, 2010
Fill the syringe to the 10 ml mark with air. The students are to predict, in writing, what mark could be reached by pushing on the plunger making sure that no air escapes from the syringe. The students are also expected to give reasons for their prediction. Undertake the compression – students need to record the observation and then try to explain what happened. Ask them to imagine what is happening if they were able to get a super-magnified view – get them to draw before and after representations.

Now fill the syringe with water and repeat the POE stages.

**Representational Perspective**

From a representational perspective the air and water within the syringe represent gases and liquids and so one can generalise the outcome of this demonstration to apply to these states of matter. This POE is a representational challenge on different levels – students are challenged to physically push in the plunger and to represent the outcome from a sub-microscopic perspective.

**Particle ideas about matter – what do we imagine?**

Rather than teaching a particle model independent of any macroscopic behaviour of matter it is better to look at a particular macroscopic behaviour of a substance and explain it using particle ideas. So we need to use the language of *the rubber band can easily stretch, how can we use particle ideas to explain this?* The students might then apply one aspect of the particle model (bonding between particles) to suggest something like *the rubber is made up of particles that are connected to each other with bonds that can stretch.* The students might represent this diagrammatically as:

However, the vibration signs are not necessary in this diagram as the purpose of the representation is only to explain the stretchability of the rubber band and not the internal energy of it (which is related to the explanation that the rubber band has a temperature).

**What do we imagine makes up a sample of matter**

**Key ideas**

A sample of a substance is a collection of particles.

- There is nothing else except the particles.
- The particles of one substance are all the same.
- The particles hold on to each other – the ‘holding power’ is different for different substances.
- The particles are always moving in some way – they have energy of movement, called kinetic energy.
- Heating gives the particles more energy of movement – they are more energetic.
- The temperature of a substance is related to the average kinetic energy (motion energy) of the particles that make up the substance.
  - The particles are in constant motion in all physical states.
  - Particles in a solid vibrate about a fixed position and are relatively close together.
  - Particles in a liquid move more freely, have no fixed position, and are still relatively close together.
  - Particles in a gas are moving freely, have no fixed position, and are far apart.
  - The lowest temperature possible for a substance is -273 °C.
- The particles that make up the substances do not share the properties of the substance they make up. For example, when wax melts the particles do not change from firm to being soft.
  - Particles are similar in size and their sizes do not change when the substance changes temperature or changes state.
- There are forces of attraction holding particles together in a solid and liquid.

**Description of Activity**

Rather than giving all the components to the particle model list above introduce some ideas at a time always referring to macroscopic observations of substances.

Begin the discussion that all chemists and other scientists think about reasons for the many, many substances having different properties. They do this by imagining what is inside the substances on a super-magnified scale.

**Imagining what’s inside a piece of paper**

Confirm with the students that, in fact, scientists do imagine that all substances are made up of tiny particles. They do this on the basis of the observations they make about substances. Now ask the question:

- What experiments can we do to show that this piece of paper is made up of particles? [We can tear it up into tiny pieces]

As a first activity get the students to draw a representation of what they might see if they had glasses which super-magnified samples of substances. Discuss with the class the different representations produced.

**Classroom example:**

In the Year 7 class three students drew their representations on the board for the whole class to evaluate. These are shown opposite. Each representation was evaluated to showing the paper as being made of particles.

**Examples of student representations**

Once establishing that the paper is made of particles, ask the question:

- What evidence do we have that the particles in the paper are connected in some way? [Because the paper holds its shape when we pick it up]

Get the students to understand that the wood particles are connected [maybe introduce the word bond]. Now give the students the following representational challenge:

**Representational Challenge:** The students are to draw a diagrammatic representation, using particle ideas, to explain the observation that when you pick up a piece of paper it holds its shape. Just like above they can begin with a diagram like:

The students will need to give representations of bonds. Again, share the different representations with the whole class. In sharing these representations they class needs to evaluate the adequacy of the representation in terms of meeting its particular purpose. That is, does the representation explain the observation that the paper can be picked up and still hold its shape.
Classroom Example:
In the Year 7 class the three representations shown opposite were evaluated by the class. The middle and right hand side representations were judged as fulfilling the purpose of the representation. The one on the left was not – it showed connectedness but not the particles.

Teachers note:
In terms of the representations that the students draw they will need to clearly label the various parts. Introduce the terminology of annotated diagram. Provide a rationale for the need to annotate. Later on, when students get a choice for the genre of representation they produce they can use the terminology of annotated diagram. In the 2008 teaching sequence the students picked up and readily used this term to describe the type of representation they were using.

The iconic particle representations of matter show particles that are vibrating and are independent of one another. This representation, if it were to be draw to explain the fixed shape of the paper, would be make the representation inadequate for this purpose.

This representation only shows that the particles have movement energy which represents, on a macroscopic scale, the substance is at a temperature greater than -273 ºC, or 0º K.

The introduction of the term ‘bond’ should not be a problem. However, the genesis of particle bonds in terms of the electromagnetic forces of attraction between the particles would be beyond the level of the students.

Imagining different substances: Representational Challenge
Show the students are sheet of paper and a sheet of plastic. Explain that the paper is more easily ripped than the plastic sheet. Their challenge it to diagrammatically represent both sheets to explain the difference.

Points to discuss would be:
- How are the different strengths of bonds represented [eg thicker/thinner lines].
- If the students have drawn a line for the edge of the paper or desk then this needs to be questioned as the particles should make the edge. There is nothing else but particles that make up the substance. If the particles make the edge then what does this suggest about them to explain why the paper has a sharp straight edge and has a smooth surface.
- Have any of the students shown space between the particles?

Classroom Examples:
In the Year 7 class students represented different substances by showing:
- Different particles
- Different types of bonds
- Different arrangement of the particles
Representing temperature

**Key Ideas:**

- The particles are always moving in some way – they have energy of movement, called kinetic energy.
- Heating gives the particles more energy of movement – they are more energetic.
- The temperature of a substance is related to the **average** kinetic energy (motion energy) of the particles that make up the substance.
  - The particles are in constant motion in all physical states.
  - Particles in a solid vibrate about a fixed position and are relatively close together.
  - Particles in a liquid move more freely, have no fixed position, and are still relatively close together.
  - Particles in a gas are moving freely, have no fixed position, and are far apart.
- The lowest temperature possible for a substance is -273 °C.

**Description of Activity**

Students need to be given the key idea that temperature is related to motion energy of the particles that make up the matter. Ask the students to represent themselves as having motion energy. 

*Temperature is a measure of the average motion energy of the particles in a sample of substance.*

This key idea means that if the particles are moving the sample has a temperature. The reverse of this is that if the particles are not moving then the sample does not have a temperature. What does this mean? Explore this with the students. What units do we measure temperature with? [Celsius] Does zero temperature mean 0 °C or can we get a lower temperature?

Make reference to the students’ responses on the pre-test to the statement: true or false?

*It is possible to heat an object to +1000 °C but it is **not** possible to cool it -1000 °C.* Many students in the Year 7 & 8 pre-tests believed this was possible.

Introduce the key idea that:

- The lowest temperature possible for a substance is -273 °C. [maybe refer to another scale called Kelvin that begins at 0; this begs the question for why scientists chose 0 °C? Defined as the freezing temperature for water]

Now we need to think about what a representation of paper would look like if we wanted to show particles that are connected and we also wanted to show that the temperature of the wood is room temperature, say 23 °C. The key idea here is in a solid, like wood, the particles need to vibrate, which gives them motion energy. But to vibrate the particles need space and they need to be connected. Explore with students what the representation might look like to show a bond and vibration.

**Representational Challenge**

The students are to use themselves to construct a representation to explain that paper at 23°C holds its shape. To do this divide the class into groups [you might need to make them gender specific as I have found in my own teaching that students at this age are reluctant to come in direct contact with the opposite sex]. The students have to resolve the issue of showing bonds (to represent a fixed shape) and movement (to represent temperature). Another issue for some students is that if they believe that particles representing a solids state are rigidly packed together with no spaces.

Give the students a few minutes each to construct their representations and then as a class each representation is evaluated for its purpose, which in this case is to explain that paper at 23°C holds its shape.

Out of this exercise it should be noted that the particles in paper, or any solid for that matter:

- Vibrate to indicate they have motion energy, and
- There are spaces between the particles [otherwise it would not be possible for the individual particles to move].
Teaching note:
The students are using this role play representation as a reasoning tool to account for the possibility that there are spaces between the particles.

Representational Challenge
The students are now to draw a diagrammatic representation to explain that paper at 23°C holds its shape. The students could draw also draw a particle representation of a sample of a substance [in a solid state] on a cold day and on a hot day.

Teaching note:
Apart from motion energy the definition of temperature above refers to the average motion energy. What does average mean here? Discuss with students the idea that although overall the objects have many, many, many particles but they don’t all have exactly the same energy – there might be some variation. This key idea about average energy will become important later when discussing the mechanisms for evaporation and smell. Some particles have higher energies than others and so their collisions with other particles within the substance maybe enough for the higher energy particle to break its bond and move into the air.

Classroom Examples:
In the Year 7 class they were asked to draw representations of a saucepan at 23 and 100 degrees Celsius. The example on the left shows annotations. Both example show movement as well as bonding.

<table>
<thead>
<tr>
<th>Animation representations of samples of substances with a temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Because representations of temperature show a dynamic process it would be beneficial to show the students some of the animations showing particles moving at different temperatures. Animations showing the particle model can freely be found through a Google search or commercial products. On can even try creating animations using such:</td>
</tr>
<tr>
<td><strong>SimChemistry</strong></td>
</tr>
<tr>
<td><a href="http://www.simchemistry.co.uk/">http://www.simchemistry.co.uk/</a></td>
</tr>
<tr>
<td>SimChemistry for Windows allows you to set up, run and interactively modify simulations on your PC representing microscopic physical systems.</td>
</tr>
<tr>
<td><strong>Pivot stickfigure animator</strong></td>
</tr>
<tr>
<td><a href="http://www.snapfiles.com/GeT/sTiCKFiGuRe.html">http://www.snapfiles.com/GeT/sTiCKFiGuRe.html</a></td>
</tr>
<tr>
<td>One can create particle shapes and quickly generate animations with this free software.</td>
</tr>
</tbody>
</table>

**Representing samples in a solid state**
In groups students are given a stick of chalk, lump of plasticine and plastic object, like a spoon. The students are to draw a super magnified view of a sample of the substance that makes up each object to show a
particular physical property of the object. The particular property is their choice and so they will need to annotate their representation to explain this.

It is very important that the representation only partly explains something about the substance. Therefore the students need to state very clearly in their representation what property of being represented. For example, if they want to show the elastic property of a rubber band they would show particles connected by stretchable bonds. Note: if they mention the sample is at a particular temperature (like room temperature) they would also need to show vibration of the particles.

Students are to construct a representation of a particular characteristic of the sample of each substance. For example, the students could represent the brittleness of chalk, the bending quality of the plastic, and the stretchiness of the plasticine.

Note: the students can’t draw the same representation for each object even though they are all samples in a solid state at room temperature. That is, they can’t show the iconic representations for solids that is often represented in textbooks.

Classroom Examples:

<table>
<thead>
<tr>
<th>Year 7 students were asked to draw a representation showing the ability of a rubber band to stretch without breaking.</th>
</tr>
</thead>
</table>
| ![Rubber Band Representation](image)

Particles ideas to represent and explain changing states of matter

There are some macroscopic phenomena that need to be explored before jumping in with explanations using particle ideas. Apart from the properties about the different states already explored the following ideas/phenomena need to be discussed/defined.

- The terminology associated with changes of state: melting/boiling/condensation/freezing [evaporation is a separate phenomenon which should be explored later]. This could be represented like this [you could also add sublimation and deposition]:

  - melt
  - boil
  - freeze
  - condense

  SOLID  LIQUID  GAS

- A sample of a pure substance melts/freezes and boils/condenses at specific temperatures called the melting point and boiling point. Show the animation [in one of the PowerPoints] which shows lead being heated. This shows very clearly that at the melting point temperature the whole substance changes state – a few degrees below and the sample will still be in a solid state, a few degrees high then all the sample will be liquid (given enough time).

- You could demonstrate to the students condensation – say with a tin container filled with ice; look on the outside of the can after a few minutes at room temperature. Discuss moisture on the windows on these cold mornings – where does the water come from?
Change of state role play

Key ideas
• Applying particles ideas through the use of student particles to explain macroscopic behaviour associated with a sample of a substance changing state.

Description of task
Set the scene by describing a particular macroscopic situation that the class is going to represent using particle ideas where the particles are students. The situation is this:
It is a hot day, you take some chocolate out of the fridge and place it on the bench and soon it begins to melt. Discuss with the students how they might represent the chocolate in the fridge. They are to represent the chocolate particles. How will they show bonds (as the chocolate is in a fixed state) and how will they represent the thermal property of the chocolate (it has a temperature)?
Once they set up a suitable representation/model ask them, ‘what is between the students in this model?’ The answer is ‘nothing’ but some may say ‘air’ in which case they don’t understand the model.
Now ask the students to represent the chocolate leaving the fridge and melting on the bench. What do they need to do to represent these using particle ideas?
Some considerations:
• The particles representing the solid are vibrating and connected (outstretched hands to one another). The overall shape of the student model is fixed.
• In changing state the connections become less, particles now begin to move around each other still being loosely connected. The overall shape of the student model becomes less fixed.
An important discussion needs to take place as to the causal reasons why a substance changes state. On a particle level how do the chocolate particles gain the motion energy to vibrate faster and break bonds? Students don’t readily come to the view that an outside body, like an air particle, through collision with the chocolate particles gives them extra energy.
Discussion might then lead to an explanation of smell – chocolate particles gaining enough energy to get free and through many collisions with air particles move around the room, some going up your nose.
The role play might be extended to include another situation, like boiling water. Students represent this change of state.
Things to note:
• Representing a gas the students are not bonded, nor should they vibrate but move in straight line until they bounce off another particle.

Animated representations of states of matter and changes of state

Key ideas
• A single representation/model cannot explain all properties of a particular substance. They cannot cover all purposes and so have a selective purpose.
• Particles ideas help us understand and explain the behaviour of matter.

Description of task
Show the students a collection of animations. Get the students to point out what the representation does show and what it doesn’t show. Show animations that show particle movements, other animations showing particle bonding.
Discuss with the students what the representations are actually showing and what macroscopic behaviour they can represent.
It is also important to discuss with the students the reasons what particles move faster and why bonds break and why particles in a gas state move to all parts of the container.
For example, show the students the graph that was given to the students in the pre-test.
To explain the flat section, the sample of wax is changing state. The extra energy from the heating source is breaking the bonds in the wax.
Energy is transferred from the heat source, such as a hot plate, from collisions in the particles of the hot plate and the particles in the wax.

**Diagrammatic representations of matter**

Students should be encouraged to explore different representations to the iconic ones found in the textbook. It should be noted that the representation doesn’t **stand alone**, it has some **specific purpose**. For example, in the Year 8 teaching sequence the following question was asked in the post-test

1. a. On the right is a picture of a section of a jigsaw. What features of the jigsaw help us to explain the features of a sample of a substance in a solid state? (2 mks)
   This helps us explain that particles hold on to each other. It also shows that the particles can’t move past each other, like in a liquid or gas state.

1. b. What features of a jigsaw don’t help explain the features of a sample of a substance in a solid state? (2 mks)
   The jigsaw helps. The jigsaw model doesn’t show that particles vibrate and particles have kinetic energy. It also doesn’t show that particles in a sample are all the same shape, size and colour.

The student’s response illustrates that he has an understanding of value of using pieces of jigsaw in explaining some property of matter. The student is also aware of the limitations of this representation to explain other behaviour.

Figures 1 and 2 below provide representations to various explanations of macroscopic behaviours of the different states of matter. For example,

- Substances change state with increasing temperature – explained by the increasing movement of the particles (Fig. 1).
- Samples of substances in a solid state have a fixed shape, in a liquid the samples can flow and in a gas can fill a container – explained by the bonds between the particles that make up the samples (Fig. 2).
Figure 2

Particle representations of various phenomena of matter

Key ideas:
- A model is a representation of idea we have about phenomena.
- Different models can represent the same thing.
- Models can only explain some aspect of the phenomena to be explained.
- Some aspects of the model will not match with the phenomena.

Description of Activity

Discuss with the students what macroscopic properties of matter the representation does show and what it doesn’t show. These are best discussed after the teaching of changes of state. One could discuss each in a class discussion or divide the class into groups each given a different slide and then each group presents their critique to the rest of the class.

<table>
<thead>
<tr>
<th>Marble in a Jar</th>
<th>Seeds in a jar</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Marble in a Jar" /></td>
<td><img src="image" alt="Seeds in a Jar" /></td>
</tr>
<tr>
<td>This shows two types of particles representing two different substances. The black particles lose their ordered arrangement to get mixed up with the white particles to represent a solid like a sugar cube dissolving in water. This model/representations doesn’t represent temperature through movement of the particles nor does it show how the sugar in the initial instance keeps its shape (bonds between particles)/</td>
<td>The left show particles in order showing a definite shape for a sample of a substance in a solid state. The middle representation show the seeds filling out the bottom of the container representing the property of liquids to fill the bottom of a container. The right representation show the seeds flying about the whole jar representing the main characteristic of a gas, which is to fill the whole container. The representations also show symbols for seed movement and showing increasing speed representing the increased temperature from one state to the next.</td>
</tr>
</tbody>
</table>
Kids in and around a bus
This represents the same type of particles (representing the same substance) in different states, orderly (solid) moving around each other (liquid) running free (gas). The kids are moving with different speeds representing different temperatures at each state.
The model doesn’t explain temperature of sample of substance in a solid state (kids on the bus should be moving; although you might assume this is what happens).

Soccer field
Spectators in stand representing fixed shape of solid. Coaches/support staff/players around the edge moving around each other representing the runniness of liquids. Platers on the field moving to all part so the field representing a gas in a container (which is represented by the soccer field).
The model shows the particles are further apart representing the liquid state which suggests that the liquid has a greater volume than the solid.

Representation of heating an iron rod
This representation shows increased movement (representing an increase in temperature) and also show some spreading of the kids which suggests that the rod expands. This is a known phenomenon – thermal expansion of metals when heated.

Popcorn
The model shows increasing movement of the popcorn to represent the increased temperature of the different states of sample of substance. What the model suggests is that particles actually increase in size for which there is no macroscopic evidence.
Representational Challenge

The diagram from your textbook represents the different states of matter. What aspect(s) of this representation do not match with the idea of actual states? How could you improve on this representation?

Source: Lofts & Evergreen (2006, p. 86)

Activities related to matter and particle idea explanations

Using the particle ideas to explain changes to matter

Key ideas

- In applying particle ideas to explain a phenomenon the idea(s) need to provide a casual reason. For example, a particle of water from a puddle of water will not fly off into the air of its own accord, nor does it ‘float around’.
- Scientists cannot see what’s inside substances on a sub-microscopic scale so that the construct representations or models to explain the behaviour that they observe on a macroscopic and microscopic scale. Different models can explain the same phenomena but any one model cannot fully explain all that is known about a particular substance. Each model only explains some aspect of the whole.

Description of Activity

In groups students are given a particular phenomenon to explain using particle ideas. For example, ask the students to use particle ideas to explain one of the following observations/properties of substances [cards could be made up that gives a visual and text description of the phenomenon – groups then select a card]:

a. Metals expand when heated.

b. The car tyre deflates when it gets a nail in it.

c. A cube of sugar dropped into a beaker of hot water soon dissolves.

d. When you take the cap off a perfume bottle you are soon able to smell the perfume.

e. The puddle of water on the ground soon disappears on a hot day.

The students have options as to the mode or modes of representations to use used. For example,

- Role play
- Annotated diagrams.
- Animation [using Pivot Software]
- PowerPoint Animation
- Physical model

In their explanations the students need to provide a reason for why a particle will change its current state. This usually involves a change in motion energy or stretching/breaking a bond.

Investigating Liquids (Taken from Hubber, 2005)

Key ideas

- Students get to do what scientists do in terms of inquiring about the macroscopic behaviour of substances and then applying particles ideas to explain that behaviour.
Description of Activity
Students are to investigate the holding power of different liquids via two methods. The first method relates to the sample’s degree of surface tension and the second method refers to the sample’s degree of runniness or viscosity.

The students are to write a report that gives their research question, explains what they did to answer the questions, produce tables/graphs to present their findings and use particle ideas to explain the findings. Encourage the students to use multiple modes of representations.

Investigating Properties of Liquids 1

Key ideas:
- The particles within a liquid are attracted to each other.
- Substances contain particles with different holding powers or different bond strengths.
- The attraction of particles at the surface of a liquid form a ‘skin’ which we call surface tension.

Description of the task
You will need:
- a series of samples of different liquid substances inside (detergent, oil, water, glycerine, methylated spirits).
- eye dropper.
- coin

The task: Determine the number of drops of each sample that can be placed on a coin without spilling over the edge of the coin.

Write up a report that gives your research question, explains what you did to answer the questions, produce tables/graphs to present your findings and use particle ideas to explain the findings. Try to use lots of different types of representations.

Teaching note:
Examples of properties are degree of colour, runniness, smell, transparency, where used, mixability with water. In the last exercise students should be encouraged to devise measurement procedures and criteria such as for surface tension, measuring the number of drops that fit on a coin, or looking carefully at the shape of a drop—the angle at the surface is a measure of the surface tension.

Investigating Properties of Liquids 2

Key idea:
- Liquids have different degrees of ‘runniness’, or viscosity, which can be measured in different ways.

Description of the task
You will need:
- a tile
- a chinagraph pencil or other marker
- a set of different liquids (e.g. water, methylated spirits, honey, detergent)
- a small funnel.

The task: Devise a way of comparing the viscosity (runniness) of the liquids using a measurement process that will enable you to enter numbers in a table. Some suggestions of method:
- the speed at which the liquid flows down a tile
- the rate at which it flows through a funnel
- the time it takes for the liquid to settle when the container is turned upside down.

Write up a report that gives your research question, explains what you did to answer the questions, produce tables/graphs to present your findings and use particle ideas to explain the findings. Try to use lots of different types of representations.
Teaching note:
For the speed down the tile, the easiest method is to put a drop of each liquid along one edge of the horizontal tile, and tilt it for a set time. Measure how far each liquid has flowed. Think about what controls are needed.

Investigating Slimes
Refer to Appendix 3. Students are to investigate the properties of the slimes they make. They are to write a report that provides a full description of the properties of each sample of slime. They should outline the tests undertaken on the slimes and show the findings of the tests. Multiple modes of representations in the final report need to be given. The students also need to interpret their findings in terms of particle ideas.

Various possibilities are possible here in terms of groupings of students. For example, students could work in pairs within a group of 4 – one pair makes three slimes, the other pair makes two. The whole group then studies the slimes.

A possible useful exercise is for the group to present all their findings on A3 poster paper.

Discussion Questions
Refer to Appendix 4. The questions can be used to revise and/or discuss key ideas associated with substances and states of matter.

Exploring the Phenomena of Samples of Substances that Dissolve in Liquids, emit Smell and Evaporate.

Key ideas
Some key ideas associated with evaporation and dissolving:

- The temperature of a substance is related to the average kinetic energy (motion energy) of the particles that make up the substance. Average here means that some particles will have a greater kinetic energy than others.
- 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.
- When substances dissolve in a liquid, their molecules intersperse amongst those of the liquid.
  - Different substances will dissolve in different liquids.

Description of Activity
Students need to understand that smell and evaporation are essentially the same phenomena. Solids and liquids don’t need to change state to expel particles in the air. Refer to the PowerPoint slides on Evaporation. Particles are ejected from liquids and solids as all the particles within a substance have varying amounts of energy – they don’t all have exactly the same amount of energy in a given state. The particle model in the slides show different coloured particles to indicate varying energies.

It should be noted that as individual particles get expelled into the air they don’t constitute a gas state. Particles on their own don’t constitute any state.

Student investigations
There are options here: to have a teacher directed activity or a short directed student activity or a student-centred investigation where they design and carry out an experiment.

Investigate how quickly smell moves in a room by lining students up and place a container with a strong smelling substance at one end of the line. Open the container and record (by students raising their hands) how quickly the smell moves along the line.

Get the students to explain the phenomenon using particle ideas.

There is a set of PowerPoint slides, Dissolving that unpack the key ideas associated with substances dissolving in liquids. This brings up the scientific terms of solvent, solute and solutions.

Various activities can be undertaken in relation to dissolving and evaporation. These include:
1. Students are to investigate what factors assist in dissolving a substance like sugar or salt in water.
2. Students are to investigate what factors assist in the evaporation of water.
3. Investigate which substances are soluble in water. Are there some substances that are not soluble in water and soluble in other solvents?
4. With each investigation students are to explain their findings using particle ideas. For example, sugar dissolves in water and chalk doesn’t because the sugar particles have less holding power than the chalk particles.

**Particle explanations for evaporation/smell**

The particles on or near the surface of the liquid or solid are bonded to neighbouring particles and have motion energy. Particles that enter the air need to have been given extra energy from an external source to be able to break its bonds and to travel away from the surface. This can occur in several ways:

- Through internal collision of particles in the substance. The key idea is that all the particles in a substance do not have the same motion energy; even though a substance might be at the same temperature, by definition, this refers to the average energy of the particles. Therefore particle in the substance with high energy might only need a little more energy from a collision to escape the surface.
- Air particles collide with surface particles to transfer energy.
- Radiation from the Sun is absorbed by the surface particles [in microwave ovens the radiation can go into the food before being absorbed].

Once the particle is released from the surface many students believe that it just floats around in the air without any mechanism for doing so. They need to know that the constant collisions with air particles accounts for this motion [which scientists describe as Brownian Motion].

With these ideas students have a causal reason for common phenomena such as how a chocolate particle can escape the bar and enter the nose to explain how we can smell chocolate.

**Investigating stuff (taken from Hubber & Tytler, 2005)**

**Description of Activity**

Students are given aluminium foil to create containers to hold household stuff. The stuff is heated slowly on a hot plate and students take observations of the stuff as it gets heated. The stuff can include **butter, candle wax, copha, margarine, cheese, chocolate**. Students should stop the heating soon after the stuff has melted.

The students need to predict which samples of the stuff (make the samples a uniform 1 cm³ each) are pure substances and which are mixtures. Which samples do they predict will begin to melt first?

In reporting on their findings the students will need to record the changes that occur to the samples. This could be done as a time sequence of pictures (using annotations to explain the changes further) for each sample.

<table>
<thead>
<tr>
<th>Start</th>
<th></th>
<th>End</th>
</tr>
</thead>
</table>

Students are to draw particle models of the samples they produce before and after heating. [If they think it is a pure substance then only one shape will be used – orderly at first to represent the solid and disorderly after it has melted. If they think it is a mixture they need to determine how many pure substances before determining how many different shapes of particles to show].
Exploring Evaporation (Taken from Hubber & Tytler, 2005)

Description of the task

You will need:

- a paper towel
- a bottle of perfume, eucalyptus oil or spray freshener
- methylated spirits
- water
- a hair dryer
- a refrigerator
- a cover.

What to do

Place a wet handprint on a paper towel and watch the handprint disappear. Where has the water gone? How quickly does smell travel? Open a bottle of perfume, eucalyptus oil or spray freshener and investigate the development of the smell throughout the room. How quickly does it spread? Investigate how the smell can be spread more quickly.

Place a drop of liquid (e.g. methylated spirits, water) onto a ceramic tile and investigate how each evaporates under different conditions—for example, in the open air, under a hair dryer, in a refrigerator or under a cover. Which evaporates the liquid faster? Use particle ideas about matter to explain why.

Teacher’s notes:

You can explain the different evaporation rates through our particle model of matter. The particles in different materials may have the same temperature but bonds of different strength. A material whose particles are weakly held will evaporate more quickly than a material whose particles are strongly bonded.

As an added evaporation investigation place a plastic bag over a group of leaves on a tree and tie the bag in place. Return after about an hour. What can you see? Explain your observation. When would be the best time to collect the most amount of water?

Testing for viscosity (Taken from Hubber, 2005)

This activity is similar to above Exploring liquids. It is possible to combine elements of both into the one activity.

Description of the Activity

The following three activities compare different liquid’s viscosity.

You will need:

- five test tubes
- milk
- tomato sauce
- water
- glycerine
- cooking oil
- a marble or a paperclip.
- a funnel with a stand
- a container
- a watch (preferably a stopwatch)
- white tile
- eyedropper

What to do

Test 1
Fill each of the five test tubes with one of these liquids: milk, tomato sauce, water, glycerine, cooking oil. Now find the time it takes for a marble or paperclip to drop to the bottom of each of the test tubes. Which liquid is most viscous?

**Test 2**

Using the eyedropper place a drop of liquid at the top of a white tile which is at an angle to the vertical. Find the time for the drop to flow down a certain distance on the tile. Which liquid is most viscous?

**Test 3**

Set up the stand as shown in the figure

![Testing viscosity](image)

Testing viscosity. Measure the time it takes for a funnel of water to empty. Now record the time for various other liquids, such as cooking oil, honey, sauce, detergent and glycerine. Which liquid is most viscous?

**Teacher notes:**

Students have some element of experimental design here. In their report they should state their aim, method including apparatus (annotated diagram), liquids used and number of trials, results (table and graphs), Discussion and conclusions – needs to include an explanation using particle ideas of matter and using multiple representations.

**Investigating gases (Taken from Hubber & Tytler, 2005)**

The following activities can be undertaken as teacher demonstrations with student involvement or as student activities in a round robin set of activities. Students would be expected to use particle ideas to explain the phenomena.

**Pushing a plastic bag into a jar**

You will need:

- a plastic bag
- a jar or plastic container
- a rubber band
- sticky tape.

Open out the plastic bag by blowing into it then fix the bag over the top of the container. Attach it firmly with rubber bands and tape, so that it is airtight. Try to push the plastic bag into the jar (without causing any air leaks). What do you think will happen? What did you discover? Was it easy? Could you open the plastic bag more by gently pulling? Try it.
Dunking a tissue

You will need:

- a tub of water at least 15 cm deep
- a glass tumbler
- a box of tissues.

Push some dry tissue paper into the bottom of a glass tumbler, so that it won’t fall out when the glass is inverted. Predict what will happen to the tissue if you push the upside-down glass underneath the water in the tub. Do you think the tissue will get very wet?

Take the glass tumbler out and feel the paper. Can you explain your observations using particle ideas?

Upturned Glass

Key idea: The atmosphere exerts a pressure in all directions.

You will need:

- a glass
- water
- a container to catch spilt water
- a piece of card or stiff paper or plastic sheet
- drinking straws
- optional items: oil, sparkling mineral water, detergent, plastic tubing of various diameters.

Fill the glass with water, to the top, and put the piece of white card on top. Hold the card while you turn the glass upside down. Make sure you do this over the tray, so it won’t matter if it spills.

What do you think will happen if you take your finger off the card?

Does it make any difference to what happens if the glass is only half full of water?

What holds the card on? (Textbooks give the standard answer: ‘atmospheric pressure’.) Does air inside the glass play a role? Will it work for a very tall glass?

Does it work with different liquids? Sparkling mineral water? Oil?

Is the card really needed? Lift water with a straw by putting your finger on the top of the straw. Try it with different size straws or with some plastic tubing.

Does surface tension play a role? Try it with some detergent in the water.

Teachers Note

Explanatory note: Most of the tricks in this section, involving water being supported counter-intuitively, are related to the same principle. The Upturned glass is a case in point, but we have never seen an explanation of this that is satisfactory. This activity has now been run with many students and adults, and the following questions come up:

- How come it works with air inside? Doesn’t the air pressure from inside push back?
- Why is the card necessary? Why doesn’t it work with just the water?
- How big a surface will the trick work with? Would it work with a bucket?
- How tall a glass would it work with? Surely there must be some limit?
- Isn’t it suction? When we try to do it with no air inside, there’s an air bubble that always goes up to the top, sucked up just like the card.

The questions and extra challenges in the activity are meant to address some of these.

The reason the card stays on is because of the outside air pressure acting upwards. The complication of the air inside can be explained thus: when the glass is upturned, the water level and card drop very slightly, increasing the volume of the enclosed air. This drops the pressure, and the card settles when the upward
pressure exactly matches the downward weight of the water and card, and the downwards but reduced pressure from the air inside.

If the card is relatively rigid you will be able to see it drops just a bit so there’s a slight gap between the card and glass rim, filled with water. The surface tension of the water allows this to happen by maintaining the surface and even providing a small adhesive force. The trick works even if the water is taken out, provided the card is wet! We’ve found a piece of thin plastic works better than paper since it doesn’t soak, but it’s also been done with table napkins and glasses of wine, when pushed! You need to be careful that the card or napkin is not too big so that it droops and breaks the water seal.

The trick doesn’t work with lemonade because the bubbles increase the pressure inside the glass. It works without a card provided the surface is small enough to maintain the surface through cohesion.

Exploring heat transfer – conduction, convection and radiation

Key ideas

- Heat is the transfer of energy from a hot object to another object or from a hot part of one object to a cooler part of the same object.
- The transfer of energy can occur as conduction, convection or radiation.
  - Using particle ideas conduction and convection involve the transfer of motion energy from high energy particles to lower energy particles through collision. The collisions result in the high energy particles losing some of their energy (slowing down) to other particles (speed up). From a macroscopic perspective the hotter matter cools down and the cooler matter heats up.
  - The transfer of energy through radiation is like how we heat up when exposed to the sun – the sun’s rays get absorbed by particles in our skin which increase their motion energy. From a macroscopic perspective this means our skin heats up.

Description of activities

An emphasis should be placed explaining heat transfer using particle ideas. When we place one end of an iron bar into a fire after awhile the whole bar heats up – students need to imagine particle collisions when explaining this effect. When representing radiation the students could use arrows in a similar way we represent light rays from a luminous source like the Sun.

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Appendix 1 Pedagogical Principles to Support a Representational Focus to the Teaching and Learning of Science

The following emerging pedagogical principles are important in supporting learning in science:

1. **A clear conceptual focus**: Teachers need to clearly identify big ideas, key concepts and their representations, at the planning stage of a topic in order to guide refinement of representational work.

2. **Explicit discussion of representations**: There needs to be an explicit teacher focus on representational function and form, with timely clarification of parts and their purposes. For example: “what is a graph and why do we have them?”

3. **Representational generation and negotiation as the focus of teaching and learning**
   a. **Active exploration through representations**: Students need to be active and exploratory in generating, manipulating and refining representations.
   b. **Perceptual context**: Activity sequences need to have a strong perceptual context (i.e. hands on, experiential) and allow constant two-way mapping between objects and representations.
   c. **Multi-modal representation**: Students need to be supported to extend and demonstrate learning through developing explanations that involve coordinating and re-representing multiple modes.
   d. **Representational challenge**: There needs to be a sequence of representational challenges which elicit student ideas, guide them to explore and explain representations, to extend to a range of situations, and allow opportunities to generate representations and integrate these meaningfully.
   e. **The partial nature of any representation**: Students need to understand that a single representation cannot cover all purposes, but needs to have a selective focus. Students need to understand the limitations of any one representation for covering aspects of an idea.
   f. **Negotiation of representations**: There needs to be interplay between teacher-introduced and student-constructed representations where students are challenged and supported to refine and extend and coordinate their understandings.
   g. **The adequacy of representations**: There needs to be ongoing assessment (by teachers and students) of student representations. The adequacy of a representation depends on the particular purpose or purposes.

4. **Meaningful learning**: Activity sequences need to focus on engaging students in learning that is personally meaningful and challenging, through attending to students’ interests, values and aesthetic preferences, and personal histories.

5. **Assessment through representations**: Formative and summative assessment needs to allow opportunities for students to generate and interpret representations.
Appendix 2 Pre-topic test

<table>
<thead>
<tr>
<th>Name:</th>
<th>Class:</th>
</tr>
</thead>
</table>

My current ideas about what makes up the things about me

1. How would you describe the following terms? Complete the sentences,
   a. A chemical is…
   b. A substance is…
   c. A molecule is …

2. In the box beside each item below use the following key to describe it:
   - S - The item is in a solid state.
   - L - The item is in a liquid state.
   - G - The item is in a gas state.
   - M - The item is a mixture of states.
   - U – I am unsure about the answer to this item.

<table>
<thead>
<tr>
<th>Chalk Powder</th>
<th>Sticks of Chalk</th>
<th>Toothpaste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoke</td>
<td>Sponge</td>
<td>Dust Cloud</td>
</tr>
<tr>
<td>Whipped Cream</td>
<td>Propane inside the bottle</td>
<td>Honey in the jar</td>
</tr>
</tbody>
</table>

3. Circle the things below that contain molecules of matter.
sunshine, air, soil, a frog, salt, lava, lightning, sea water, a mars bar
4. Some water was placed in a beaker, and its mass was measured using a balance. The mass of beaker and water was 200 g. Then 10 g of sugar was weighed out. The sugar was added to the water, and sank to the bottom. 10 minutes later the sugar could not be seen.

\[ 200 \text{ g} + 10 \text{ g} \rightarrow \text{ g} \rightarrow \text{ g} \]

a. Fill in the boxes to show what you think the mass of the beaker and its contents would be when the sugar was first added, and then after it could no longer be seen.

b. Where did the sugar go? Explain your answer.

5. The picture below is the top of a syringe. The needle part is missing.

a. If you put some air into the syringe, and put your finger over the opening in the end and then you tried to push the plunger in, what would happen? Explain your answer.

b. If you filled the the syringe with water, and put your finger over the opening in the end and then tried to push the plunger in, what would happened? Explain your answer.
6. The picture shows a lit candle. Around the wick the wax has begun to melt and is in a liquid state. Imagine that you are able to see inside the wax to get a super magnified view. In the circles and lines below draw and write about what you might see.

---

7. Each statement tick the box you feel most fits your understanding of the statement.

<table>
<thead>
<tr>
<th>#</th>
<th>Statement</th>
<th>True</th>
<th>False</th>
<th>I Don’t Understand</th>
<th>Not Sure</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A chemical is always a substance that is man-made.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>All objects consist of very tiny particles called atoms.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>A molecule is a tiny particle that consists of more than one atom bonded to each other.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Even with the most powerful of microscopes scientists have still not been able to see the atoms.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Oxygen is substance that is always a gas.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>When a substance freezes the temperature must always be less than 0 °C.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>It is possible to heat an object to +1000 °C but it is not possible to cool it -1000 °C.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>When wax melts the molecules that make up the wax change from being hard and firm to being soft and ‘gooey’.</td>
<td></td>
<td></td>
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<tr>
<td>I</td>
<td>To be able detect the smell of chocolate molecules of the chocolate need to go up your nose.</td>
<td></td>
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<tr>
<td>J</td>
<td>When a substance condenses it changes from a gas into a liquid.</td>
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<tr>
<td>K</td>
<td>A closed bottle with small amount of water at the bottom is left in the sun. After awhile, when the water has evaporated, the mass of the bottle is now less than before.</td>
<td></td>
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<tr>
<td>L</td>
<td>The molecules inside liquids and gases are moving but in solids they are stationary.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>M</td>
<td>The bubbles that are created when water boils are made of either Air, or Hydrogen and Oxygen.</td>
<td></td>
<td></td>
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<tr>
<td>N</td>
<td>In the spaces between atoms of an object there is air.</td>
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</tbody>
</table>
8. A lump of solid wax was placed into a container and heated. The Temperature of the wax was measured every minute during heating. The Temperature and Time measurements were then placed into the graph shown below.

![Heating Wax Temperature versus Time Graph]

a. What temperature was the wax after 6 minutes of heating?

b. You should notice on the graph that the temperature stays constant between 12 minutes and 14 minutes. What do you think has happened here?

9. Imagine you were a particle of perfume inside a bottle of perfume when the lid is closed. The lid is left open and, after awhile, no perfume is left in the bottle. The owner of the bottle notices a strong smell of the perfume in the room.

Describe what would be happening to you [as a particle of perfume] – use diagrams if that makes it easier to explain.

Thank you for your responses
**Appendix 3 What do you know about matter?**

What do you know about matter?

Sort these objects into separate groups. Give each group a name and describe the properties of the group. Now think of another way to sort these objects? What would be the names or labels, and descriptions, which you would give to each group?

<table>
<thead>
<tr>
<th>Rubber Flipper</th>
<th>Drinking Water</th>
<th>Apple</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Rubber Flipper" /></td>
<td><img src="image" alt="Drinking Water" /></td>
<td><img src="image" alt="Apple" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sunscreen</th>
<th>Sea Water</th>
<th>Towel</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Sunscreen" /></td>
<td><img src="image" alt="Sea Water" /></td>
<td><img src="image" alt="Towel" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Oxygen in the tank</th>
<th>Helium inside balloons</th>
<th>Sand</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Oxygen in the tank" /></td>
<td><img src="image" alt="Helium inside balloons" /></td>
<td><img src="image" alt="Sand" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Slime</th>
<th>Bubble Wrap</th>
<th>Smoke</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Slime" /></td>
<td><img src="image" alt="Bubble Wrap" /></td>
<td><img src="image" alt="Smoke" /></td>
</tr>
</tbody>
</table>
Appendix 4 Investigating Slimes (taken from Hubber, 2005)

Investigating Different Slime Recipes

PLEASE NOTE: None of the ‘slimes’ produced in this experiment are safe to dispose of in the drainage or storm water system due to the use of borax as an ingredient. Carefully wrap the ‘slimes’ in newspaper or plastic bags for disposal in the rubbish bin.

You must not eat any of the slimes that are produced!

Ingredients used in several different recipes:

- 4% Borax Solution. Prepare this by adding 40 grams of Sodium Tetraborate (Borax) to 1 litre of water. Stir well to mix. There will be some solid left in the bottom of the beaker, indicating that the solution is saturated.
- PVA glue – obtainable from craft and hardware stores.
- 10% Polyvinyl Alcohol solution – solid PVA is difficult to dissolve in water so it is much easier to buy the ready made PVA solution from the chemical stores.

Recipe 1

Materials needed:
- 50 mL of PVA glue
- 50 mL of water
- Food colour
- 20 mL of 4% Borax solution

Method:
Mix the water and the glue together to create a thick solution. Add a drop or two of food colour and stir until the colour is evenly distributed. Slowly add the borax solution, while stirring. The ‘slime’ will quickly form around the stirring rod and can be removed from the beaker and kneaded to make it thicker and drier. Wear disposable gloves while handling the ‘slime’.

An alternative method involves making the ‘slime’ in a resealable sandwich bag. Place the mixture of glue water and food colour into the bag. Add the borax solution. Seal the bag and mix the contents thoroughly.

Recipe 2

Materials needed:
- 50 mL of water
- 50 mL of PVA glue
- 1 teaspoon of talcum powder
- Food colour
- 20 mL of 4% Borax solution

Method:
Mix the water and the glue together to create a thick solution. Add a drop or two of food colour and stir until the colour is evenly distributed. Add the talcum powder and stir until thoroughly mixed. Gradually add the borax solution with continuous stirring. The ‘slime’ will form around the stirring rod.

Wearing disposable gloves remove the slime from the container and work it between your fingers. After kneading it for a short while it will become firmer and dryer. You may need to wipe your hands on paper towel to remove excess moisture. DO NOT wipe the slime with paper towel as it will tend to stick to it. You can roll and knead the slime in extra talcum powder that has been sprinkled on the benchtop to increase the firmness and dryness of the slime.

This mixture can also be created in a resealable sandwich bag.

Recipe 3

Materials needed:
- Water
- Ethanol or methylated spirits
Boric acid powder
Food colour
PVA glue
4% Borax solution

Method:
Mix to form a solution 100 mL of water, 10 mL of ethanol and a spatula spoonful of boric acid powder. Mix well. Add food colouring. Mix 20 mL of this solution with 50 mL of PVA glue and stir until the colour is evenly distributed. Add the borax solution, with constant stirring, 5 mL at a time until a slime of the desired consistency is formed. Once the slime has formed it can be kneaded with gloved hands or in a resealable bag to increase dryness and firmness.

Recipe 4
Materials needed:
Guar Gum (available from health food stores)
Water
Food colouring
4% Borax solution

Method:
Measure 1 litre of warm water into a large beaker. Add a few drops of food colouring. Very slowly sprinkle two teaspoons of the powdered guar gum onto the surface of the water, stirring constantly. Try to avoid the guar gum forming into clumps as these are more difficult to dissolve. Once the guar gum is completely dissolved the solution is ready to use.

- Take 100 ml of the guar gum solution and mix it with 5 mL of the borax solution.
- Stir well to mix.
- For a thicker slime you may need to add more borax solution.
- The mixture can be prepared in a resealable sandwich bag.

Recipe 5
Materials needed:
PVA solution
Borax solution
Food colouring

Method:
Pour 50 mL of the PVA solution into a resealable bag. Add food colour and mix thoroughly to evenly distribute the colour. Slowly add 10 mL of the borax solution and then seal the bag and knead the contents to mix thoroughly.

Slime Investigations:

- Compare and contrast the recipes:
- Which recipe made the best slime?
- How do you define ‘best’?
- What criteria did you use to identify which of the 5 slimes you preferred?

Further Hints
Too sticky or too runny?
If your ‘slime’ is too sticky or too thin try kneading it for a while. Kneading it in your hands will help the ingredients to mix together and will also remove some of the water. If you are still not happy with it prepare a solution of 1 mL of the borax solution mixed with 10 mL of water. Dunk the ‘slime’ into this solution, remove and knead some more. This step can be repeated several times.

If Borax is not allowed to be used by students in your region it will be necessary for the teacher to manage this ingredient.
It has been suggested that Epsom Salts are a suitable replacement for Borax but the slime created will not be as firm as fewer crosslinks between the polymer chains are created.

**Appendix 5 Discussion questions**

**Discussion Questions**

1. Maeve is making a birthday cake and wants to put a layer of cream in the middle. She opens the tub of pouring cream and finds that it is quite runny, like shampoo.

   Should she use this for the middle of her cake? Why/why not?

   Maeve pours the cream into a bowl and, using a whisk, she stirs quickly. After a while the cream becomes thick and stiff. Maeve did not add any other ingredients to the bowl.

   What do you think has happened to the cream?

2. Tran is making a fresh bread sandwich and John is making toast for lunch. The butter is very hard and Tran finds that it is difficult to spread it on his bread. Straight after John’s toast pops out of the toaster he easily spreads the butter on.

   Why is it harder to spread the butter on the bread than the toast?

3. Just before Kim leaves the sauna she pours a jug of water onto the hot coals. She quickly leaves and as she is turning the ‘off’ switch she sees through the window that the sauna is full of steam. Sometime later she passes by the window and notices that the steam has gone. She opens the door to find that the sauna has cooled. She also notices that the bench and walls are wet when before they were dry. The door had been sealed tightly so where did the steam go? Why did this happen?

4. One of the events at the Wacky Races is the ‘No-Spill Dash’. Competitors must run 10 laps of the oval with a cup full to the brim of a substance. There is no lid on the cup and the competitors have to try not to spill anything as they run. The competitor in each lane has a different substance in their cup according to the list below:

<table>
<thead>
<tr>
<th>Lane</th>
<th>Substance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>water</td>
</tr>
<tr>
<td>2</td>
<td>honey</td>
</tr>
<tr>
<td>3</td>
<td>cold margarine</td>
</tr>
<tr>
<td>4</td>
<td>Helium (from a balloon)</td>
</tr>
</tbody>
</table>

   - It is impossible have a cup full of one of the substances on the list. Which one is it? Why?
   - Of the remaining three cups, which one would be the easiest to run with without spilling? Why?
   - Which cup would be the hardest to run with without spilling? Why?
5. As a reward for working safely in the science lab, Kaol, Su Lin and Rachael were each given a chocolate bar in a plastic wrapper. They decided to save them until lunch time so put them in their bags and went off to their PE lesson. During the lesson somebody fell on Sue Lin’s bag and Rachael’s bag was left in the sun.

At lunchtime, the students pulled their chocolates from their bags. Sue Lin found that her chocolate had been crushed and now only filled three quarters of the wrapper. Rachael found that her chocolate bar had melted and now only filled half of her wrapper. Kaol’s chocolate bar had not changes and filled the full length of the wrapper. Rachel and Su Lin said that it was unfair as Kaol had more chocolate to eat than they did.

Were they right to think that? Explain why/why not.

6. Tran has a balloon filled with helium that she was given for her birthday. She has left it inside the car for 4 hours on a very hot day. When she comes back to the car she notices that it is a lot larger. She wonders why.

Draw a diagram of the helium gas particles that are inside the balloon when she first placed it in the car and then again later when she came back to the car.

7. John has been watching and has noticed that the electricity wires outside his house seem to droop on summer day. He isn’t sure what is happening? What do you think has been happening? Explain using a diagram that shows what is happening inside the wires?