Activities for Teaching and Learning about Changes to Matter:

Dissolving and Chemical Change

Russell Tytler and Peta White, Deakin University

The fourth in this series for *Let's Find Out*, this article based on the teaching resource: "Ideas for Teaching Science P-8", that has numerous science activities and advice for teachers and has been freely available on the Deakin STEME (Science, Technology, Engineering, Mathematics and Environmental Education) Education Research group's website (https://deakinsteme.org/resources/). Each issue in this series features a new topic. In this article we extend the previous article on changes of state (solids, liquids, gases, melting, evaporating) to deal with dissolving and chemical changes. Again, we draw on recent research into students constructing and evaluating representations such as drawings and models (Tytler, Peterson, & Prain, 2006; Tytler, Haslam, Prain, & Hubber, 2009; White, Nielsen & Tytler, 2020), and interdisciplinary approaches linking science and mathematics, to refine and extend these activities (see the 'Interdisciplinary Mathematics and Science' (IMS) project https://imslearning.org/ for access to the teaching and learning sequences used in this research), while retaining a focus on the key ideas and on students' alternative conceptions in the topic (Tytler, Ferguson, & White, 2019).

Chemical Science in the Victorian Curriculum

The Victorian Curriculum focuses on a progression of ideas about the variety of materials, their properties and use, and changes to materials that are reversible (changes of state, dissolving) and irreversible (involving chemical change).

Science Understandings

Level F-2

Objects are made of materials that have observable properties
Everyday materials can be physically changed or combined with other materials in a variety of ways for particular purposes

Level 3-4

A change of state between solid and liquid can be caused by adding or removing heat
Natural and processed materials have a range of physical properties; these properties can influence their use

Level 5-6

Solids, liquids and gases behave in different ways and have observable properties that help to classify them
Changes to materials can be reversible, including melting, freezing, evaporating, or irreversible, including burning and rusting

In this article we focus on activities involving dissolving and mixing and on chemical changes in which new substances are formed.

Dissolving and chemical changes to matter

Introduction

Many of the activities involving changes to matter relate to common phenomena, but challenge students to look at them in new ways. In this article we start with activities on dissolving and mixing, highlighting the important distinction, but with both phenomena representing a physical change. We follow with some chemical change activities which also involve 'mixing' of substances but in these cases, new materials are formed, with different properties. The formation of a gas in an acid-base reaction is an example of this or burning which involves a reaction between oxygen and a substance to form, for instance, carbon in the case of organic material, and carbon dioxide. Distinguishing between physical and chemical changes is not always easy, particularly if you do not have access to the concept of atoms and molecules.

You can get several surprising effects from chemical reactions. In the early and middle school years, only simple reactions are appropriate, such as that between sodium bicarbonate (baking powder) and vinegar (or any mild acid) to produce carbon dioxide. This reaction is the basis for many intriguing activities, with effects that depend on the gas production. Cooking provides some excellent examples of both physical and chemical change and is a useful and popular activity in classrooms. In the 'kitchen science' section of this topic you can focus on techniques for observing and understanding the changes that occur in cooking and use some novel recording strategies.

Some key concepts of dissolving and chemical change

The activities in this topic are designed to explore the following key concepts:

- Changes to materials can be physical (dissolving and mixing), involving re-arrangement of existing substances, and chemical (bicarb reactions, burning), involving the production of new substances.
- When substances form a mixture in a liquid rather than dissolving, they may remain as small solid particles (as with dust).
- When substances dissolve in a liquid, their molecules intersperse amongst those of the liquid.
- Different substances will dissolve in different liquids.
- The forms that substances can take are complex and varied, including suspensions and colloids, mixtures, etcetera… As such they can be hard to classify.
- Substances can react together to form new substances that are quite different in their properties.
- A gas is a possible product of a chemical reaction.
- Combustion is a chemical reaction.
- A flame needs oxygen to keep burning, as the oxygen reacts with the burning substance.
- Substances can be grouped (e.g. acid/base) according to their chemical properties.

Students' alternative conceptions of dissolving and chemical change

Research into students' ideas about this topic has identified the following non-scientific conceptions:

- Mixing with water or dissolving are confused with melting
- Substances are thought to disappear when they dissolve

There is a tendency to think of reactions in terms of physical change:

- Phenomena such as bubbles are simply effects: they are not seen in terms of the formation of substances. 'Mixing things makes them fizz'. Thus, the categories of 'substance' and 'effect' can be interchangeable.
- A chemical reaction is not an interaction of ingredients but one ingredient that plays an active role.
- Substances have an ongoing history, so that a gas formed in a chemical reaction is thought to have been present in some form in the initial ingredients, and that carbon formed from burning is in fact a burnt form of the original substance.
- When a candle burns it simply melts or changes to vapour in the air.
- Oxygen or air is an enabling ingredient in the burning process but is not consumed in the process.
- Reactants retain their identity in a chemical reaction.

Dissolving

Children often confuse dissolving (one substance combined with another) with melting (a change of state as a result of heating). This confusion is embedded in some metaphorical language ('She dissolved into tears'). Children will be familiar with many instances of dissolving, mixing, and melting which can be drawn on to clarify the distinction and sharpen their understanding of what is happening.

Activity 1: Drops on a sugar cube

Teaching note: Young children will sometimes say something like sugar has 'disappeared' into water when it dissolves. This is taken at face value by some, but it is likely that they simply mean it can no longer be seen. One way of heading off this ambiguity is to use coloured solutes such as raw sugar or jelly crystals so that the continuing presence of the substance is obvious. In this activity you can see that the sugar is still present in the pool of water because of its oily texture and viscosity, obvious when a drop lands on the surface. It also tastes sweet.

Key idea: Sugar dissolves gradually in water. It disperses into the water but is still present in dissolved form.

You will need, for each group: An eyedropper; water; a sugar cube; a small dish; a timer (can be a class timer – e.g. a phone).

Instructions:

- Students add drops of water 10 at a time to a sugar cube on a saucer
- After each 10 drops they draw what is happening, with a brief description in their books

FOCUS QUESTION: "What is happening to the sugar?" Students should also consider the nature of the liquid, as it becomes increasingly viscous.

Key question: Where has the sugar gone? (Students could taste the liquid at each stage)

Explanatory note: When a substance dissolves in water or another liquid (formally called 'the solvent') it breaks down into its component molecules and disperses completely amongst the water molecules. If children do not have a view of matter being made up of particles, they will not have access to this model, but the idea of matter breaking up and dispersing into water can be talked about even with young children. For the middle years, it may be appropriate to role-play the break-up of matter into particles, or to make drawings of the way they might appear in a 'really powerful microscope'.

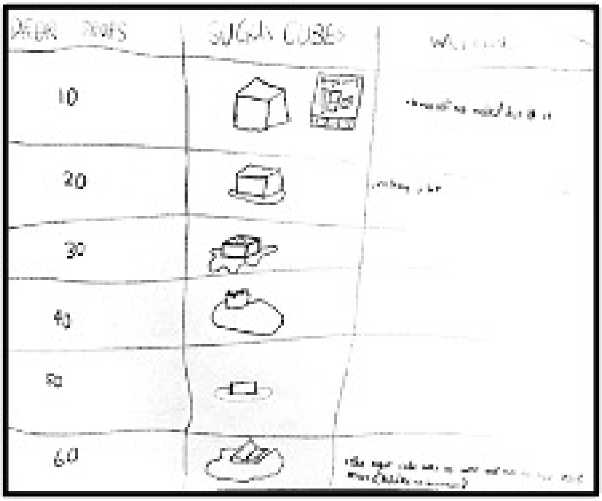

Figure 1: Year 2 student work.

With this activity, it would be useful to discuss with students the difference between melting and dissolving. As can be seen from the example, children can interpret this as the sugar cube 'melting' as a response to the way it collapses.

Activity 2: Dissolving and mixing

Key idea: Dissolving is not the same as mixing. With dissolving the solution is clear or translucent. Mixtures are cloudy since the substance is often still in solid form, suspended in the liquid.

You will need, for each group: Three plastic cups; water; small amounts of sand; flour; sugar (raw sugar is best); paddle pop stick for stirring.

Instructions:

- Introduce students to the sand, flour, brown sugar (everyday materials) and water that are going to be combined to see "what will happen?".
- Lead a discussion about students' previous experiences of mixing things with water.

Predictions: Invite students to make predictions about what will happen in each case. Record student ideas on the board (e.g. mix, float, sink, separate, dissolve etc.).

For young students, model the mixing of sand in water and observation of what happens over time. Pay attention to the language used, and challenge students to think about how they might record observations immediately after mixing in each case, then over time (perhaps every 5 minutes for 20 minutes although this could be strategically varied).

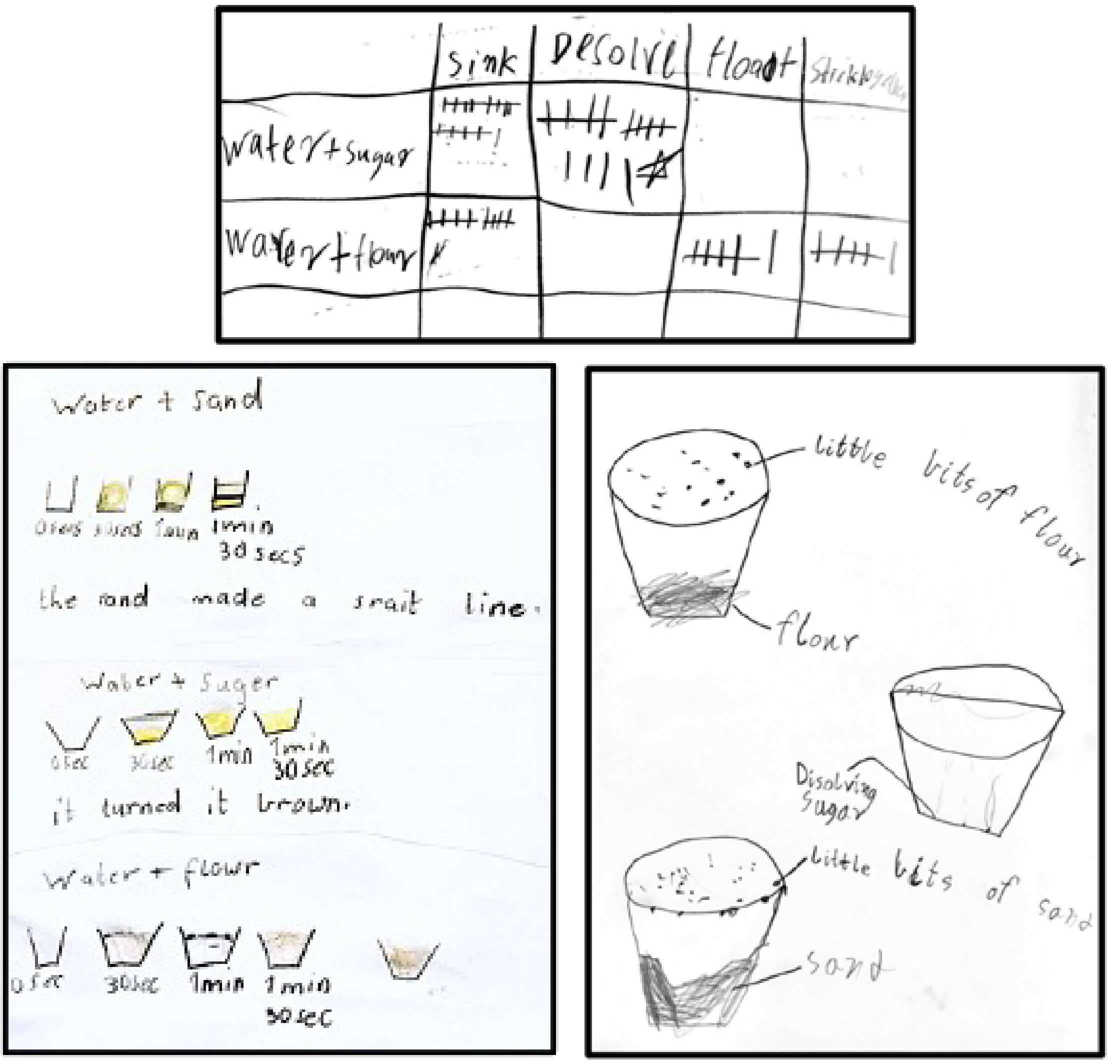

Figure 2: Examples of Year 2 student work.

Activity 3: Exploring the dissolving of sugar

Key ideas: The rate of dissolving depends on temperature, being faster in hot water. Different sugars (white sugar, coffee sugar, raw sugar) dissolve at different rates depending on their grain size

You will need, for each group: Different types of sugar (castor sugar, white sugar, raw sugar); three plastic cups; water; paddle pop stick for stirring.

Instructions:

These explorations enable the design of a fair test, to compare conditions. Discuss the need for a fair test and what this means (keeping all variable the same – except 1). This may involve each group 'testing' a different type of sugar and comparing results across the class.

Predictions: Challenge students to make predictions about what will happen in each case.

Pose the question: Will sugars always dissolve at the same rate? What might the rate of dissolving depend on? How could we test? What will we need to keep the same, and what will differ? How will we record our results?

Challenge students: Explain the results in terms of a representation of what is happening, or what you would see if you had a really powerful microscope.

The following examples are from Year 5 students who compared sugars, or temperature, who had been introduced to the idea of molecules and how they can help us understand what is happening.

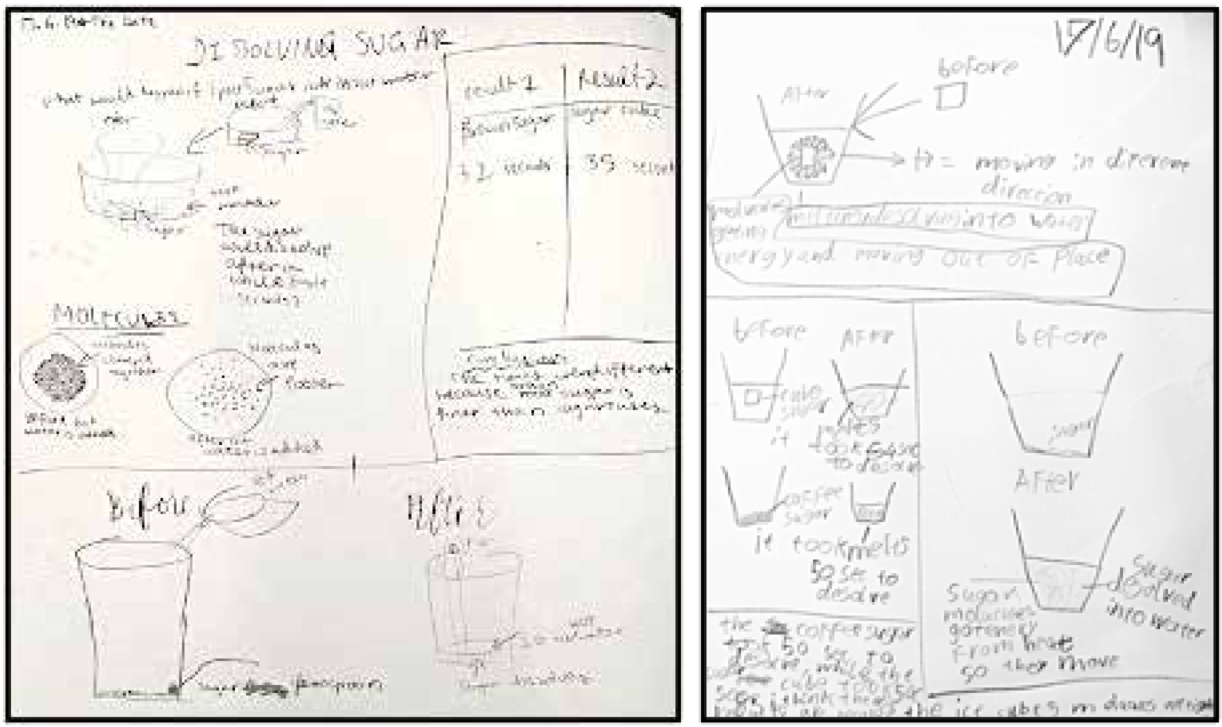

Figure 3: Year 5 students' representations of a dissolving sugar investigation.

Gas and Bubbles

Key ideas: In a chemical reaction, substances change to new substances with entirely different properties. Substances can totally change in a chemical reaction. A gas can be formed in a chemical reaction.

Teaching note: Zip-lock sandwich bags are ideal for demonstrating gas production as they can be quickly sealed, and the bag will expand as the gas is produced.

The *Froth and bubbles* activity demonstrates a chemical reaction between the baking soda and the vinegar and is a useful contrast to the dissolving activities we have just described. The quantities suggested inflate the bag nicely, but you may have to deal with demands to try the experiment again using much larger quantities. It is quite possible to blow a hole in the bag with greater amounts, and no real harm will be done. This is an acid–base reaction to form water and a salt (sodium acetate) and carbon dioxide. The questions are designed to draw attention to the fact that the substances are no longer the same. Students might try, after the immediate froth has subsided, to add more bicarb to see if any vinegar is left. Or add more vinegar to see if any bicarb is left. If they smell inside the bag, they will notice the vinegar smell has almost gone. What is left is a salt dissolved in water. The vinegar and sodium bicarbonate no longer exist, but their constituent atoms now form quite different materials.

Students understandably will have trouble with this idea. Younger students (up to age ten or so) tend to say 'The baking soda caused the bubbles' or 'The vinegar caused the bubbles', treating the reaction as the result of their action in adding the active substance. It is important to emphasise the idea of the substances interacting to cause the effect. They will also need convincing that the vinegar and baking soda are now gone. They will argue that the blowing up of the bag was due to the bubbles, rather than a gas produced by the reaction. The confident grasp of the gas concept is difficult for students even into upper levels of primary school

Activity 4: Froth and bubbles

You will need:

- a clip-lock sandwich bag; vinegar; baking soda; a cup measure; a teaspoon.

Instructions:

Measure a quarter of a cup of vinegar into a zip-lock sandwich bag. Add a teaspoon of baking soda and quickly shut the bag.

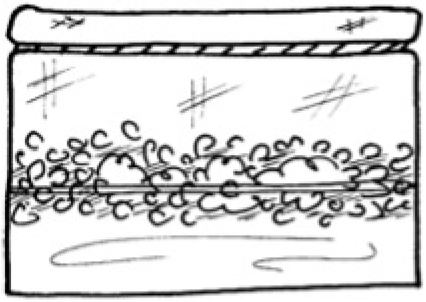

Figure 4: A Zip-lock bag containing reacting vinegar and bicarb soda that is producing carbon dioxide gas water and salt.

Pose the question: What happens to the baking soda? Where has it gone? What has happened to the vinegar? Has it changed?

Encourage students to open the bag and smell – is the vinegar smell still as strong? (the vinegar has reacted to form water plus a salt).

Challenge students: Represent what has happened with an annotated diagram.

Activity 5: Balloon blowout

Key idea: Carbon dioxide and air have different properties.

You will need: a small plastic soft-drink bottle; a balloon; a spoon; a funnel; vinegar; baking soda.

Instructions:

- Pour vinegar into a small plastic soft-drink bottle, to a depth of 2 to 3 cm.
- Put a teaspoon of baking soda into a balloon (you could use a funnel) and fit the mouth of the balloon tightly over the mouth of the bottle.
- Up-end the balloon to allow all the baking soda to fall into the vinegar.

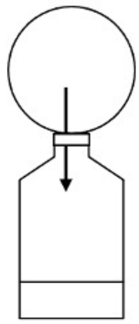

Figure 5: A balloon containing bicarb soda is secured over the mouth of a soft-drink bottle with vinegar in it and upended - producing carbon dioxide gas water and salt.

Pose the question: What causes the balloon to blow up? What has happened to the baking soda, and the vinegar? What is in the balloon?

Challenge students: Represent what is happening using an annotated diagram.

Take the balloon carefully off the bottle, sealing it and tying it. Blow up another balloon to the identical size. Both balloons are now full of gas – carbon dioxide in one and air in the other. You can compare them.

Do they feel the same? Do they drop at the same rate?

How can you measure the amount of gas produced?

Teaching note: This activity allows further exploration of how a balloon full of carbon dioxide might behave compared to a balloon of air. The carbon dioxide is more dense than air and the balloon is heavier. It falls more quickly to the ground than the equivalent air-filled balloon.

Activity 6: Dancing raisins

Teaching note: All the activities with baking soda are based on the same principle, but the bubbles in this activity are used for different purposes. The Dancing raisins activity will go for quite a while and is great for close observation over longer time. Bubbles formed by the reaction of bicarb soda and vinegar adhere to the surface of the raisin and act as rafts which float the raisin to the surface. Once they reach the surface the bubbles pop, releasing the carbon dioxide to the air, and the raisins fall again.

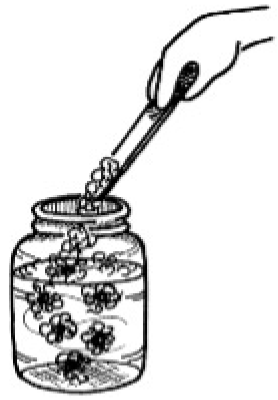

Figure 6: Raisins in a jar rising and falling

Key idea: Gases may be a product of a chemical reaction.

You will need: a small jar or glass; a spoon or icy-pole stick; vinegar; raisins; baking soda

Instructions:

Fill the small jar with vinegar, so it is three-quarters full. Put in six raisins. Do they sink or float?

Use an icy-pole stick or spoon to put in a small amount of baking soda and stir. Look carefully at what is happening to the raisins.

Pose the question: Why are they going up and down? What is causing the bubbles? What is in the bubbles? What has happened to the baking soda? Is it still there? What has happened to the vinegar?

Once the bubbles stop, how can you get them started again? (if there is still unreacted vinegar, putting more bicarb in will start the reaction again).

Challenge students: Represent what is happening to the raisins, perhaps as a four-stage cartoon narrative story to explain the up and down movement. Annotate the diagrams to show what substances are involved (vinegar and baking soda reacting to produce a gas (carbon dioxide).

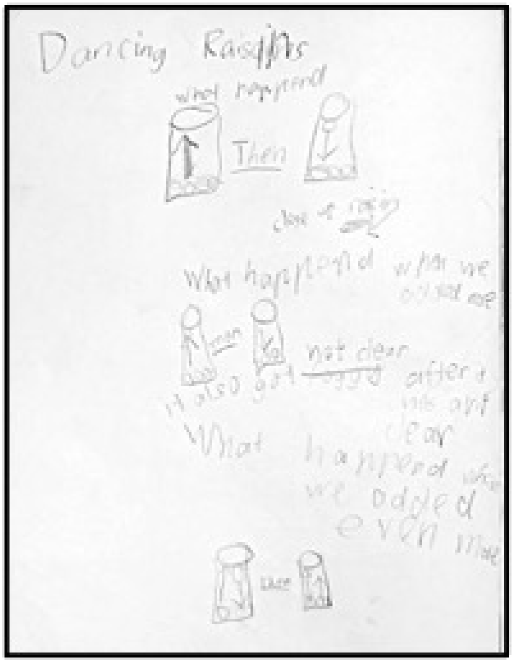

Figure 7: Year 2 student representation of dancing raisins.

Activity 7: Alka-seltzer action

Key idea: Carbon dioxide extinguishes a flame and is heavier than air.

You will need: a small jar, with a candle that comes to just (1 cm) below the rim, and water in the bottom.; an Alka-seltzer tablet; matches; water.

Instructions:

Light the candle that is standing in the jar. Break an Alka-seltzer tablet into four pieces and carefully drop the pieces into the water.

Pose the question: What do you see? What is causing the bubbles? What is in the bubbles? Why does the candle go out?

Challenge students: Represent what they think is happening to cause the bubbles, and to cause the candle to go out.

Teaching note: In this activity, carbon dioxide is produced once again. If you look on the ingredients of Alka-seltzer you will see that they include citric acid and sodium bicarbonate, which react when dissolved in water. Using vinegar instead of water with the Alka-seltzer tablet hastens the reaction. This activity can also be done with baking soda and vinegar.

The carbon dioxide produced is heavier than air, and gradually builds up in the jar until it snuffs out the candle. You can try a further demonstration — the carbon dioxide in the jar can be poured onto another lit candle, to snuff it out.

Students, of course, will have other ways of explaining this. We worked with teachers of Years 1/2, 3/4 and 5/6 to run a unit on bubbles which included some of these activities. A couple of months later we ran this Alka- seltzer activity with the same students and asked them to write down their ideas. Table 1 gives the percentage of each year level giving different explanations.

Figure 8: A candle in a jar with water and Alka-seltzer creating carbon di-oxide.

Explanation for candle going out	**Year ½** **n = 24**	**Year ¾** **n = 26**	**Year 5/6** **n = 22**
Carbon dioxide was produced	0	0	18
Reference to gas produced	0	12	32
Because of the air in the bubbles	4	23	9
Because of the bubbles, wetness, vinegar, powder, other …	96	65	41

Table 1: Student's ideas about why the candle goes out.

It is clear that the younger students focus on the perceptual features of the activity, and it is only the upper-primary students who have a reasonably confident grasp of the idea of a gas being produced.

Kitchen Science

Cooking can introduce a wealth of observations and interpretations of changes to materials. Generally, activities involving heating are not appropriate for students in the early years, however for young children it is possible for the teacher to demonstrate the cooking process and distribute results to groups for investigation and display, or to enlist adult help to work with children in groups. We have done this successfully with two adults in a Year 2 class with groups making pancakes. Bread can be baked with an early years school class observing and commenting on each stage, and taking samples of the ingredients and the mixture away to explore and write about (see the 'chemical science' sequence at https://blogs.deakin.edu.au/sci-enviro-ed/video-material/)

As a general principle, in cooking activities we are wanting students to consider the underlying science, so that what is normally thought of as a generalised effect ('bread rises in the oven') becomes explainable in terms of changes to substances ('gases are produced by a yeast reaction to make bread rise, the evidence of which can be seen in the texture of the bread – the small holes throughout'). In the interests of space, we present one cooking activity here, with Year 2 student work gathered in our IMS 'Chemical Science' sequence (https://imslearning.org/). Further cooking activities can be found in the 'Ideas for teaching science P-8' booklet on chemical change (https://blogs.deakin.edu.au/sci-enviro-ed/early-years/).

Activity 8: Making pikelets

Key ideas: The many physical and chemical changes involved in cooking (mixing, dissolving, evaporation, burning, changes to texture). The use of a freeze-frame technique for investigating change over time.

You will need: the ingredients for piklets (see below); a table to collect data; recipe; pens; and a timer.

Pikelet recipe (makes approximately 12 pikelets)

Utensils	Ingredients	Instructions
Measuring spoon and cup Sieve Bowls Wooden spoon or Beater Electric frypan Spatula	2 teaspoons sugar 1 egg 1 cup (126 g) self-raising flour ¾ cup milk Oil or butter for cooking	Beat sugar and egg together until creamy Pour creamed mixture over the sifted flour and stir in the milk, a little at a time, beating until smooth Heat a little butter in the frying pan Drop spoonfuls of mixture into hot pan and turn with spatula when mixture begins to bubble (see Figure 9).

Instructions

These instructions are written for the teacher to take charge of the cooking process as a demonstration, but it is possible, depending on the age of the students, to have students mix and cook in groups, under supervision.

The recipe can be modified for smaller amounts, and we found it productive as an exercise in measuring, and using fractions, to challenge the class to reconstruct the amounts for making different numbers of pikelets.

Discuss with students how best to construct a clear record of what happens at the stages of preparation and cooking (table, or worksheet). Challenge children to record the changes that occur. Describe these as completely as possible and explain in terms of what is happening to the material. For instance, is the mixing a physical or chemical change? What is causing the bubbles? What is the black stuff?

Mix the ingredients according to the recipe. As you proceed, students should note the changes that are occurring in each ingredient. What happens to the butter? Is the flour mixing or dissolving?

Start cooking one pikelet then wait 30 seconds to start the next. Repeat for as many as you can fit into the frypan. Ensure they of identical size. Turn them in sequence and with 30 second intervals. Manage the heat of the frypan (if it gets hotter each pikelet will take less time to cook).

As the cooking proceeds, students should note carefully the changes that are visible at the top surface of the pikelets. You could remove one with only one side cooked to 'freeze' this process in time.

Teaching note: The changes to materials you will notice include the mixing of flour to form a paste, the change in consistency of the materials, the dissolving of the sugar and the mixing together of the yolk and egg white, the beating of air into the sugar and egg mixture. For the cooking: the melting of butter, the formation of bubbles of steam as the water evaporates and carbon dioxide from the flour being heated, the hardening of the mixture as it lightly burns, the drying of the mixture on the inside of the pikelet as heating proceeds, and the small of the butter and pikelets.

Figure 9a: 4 pikelets at different stages of cooking (30 second intervals). Note the bubbles in the unturned pikelets and the colour of the turned pikelet. Also note the bubbles at the edge of the unturned pikelets.

Figure 9b: 4 cooked pikelets.

Discussion

This article has described eight engaging activities focused on changes to materials, in this case dissolving, mixing and different types of chemical change. An emphasis in these activities is on students exploring

Figure 10: Year 2 students' representations of changes in the pikelets during cooking.

phenomena, with an emphasis on close observations leading to representations that describe and explain what is happening. This includes the slowing down of observation using sequenced observation and description at time intervals, and the construction of representations at the molecular level for older students, or of 'really powerful' microscope images for all students.

The student work samples included comes from Year 2 and Year 5 students in our Australian Research Council IMS project where we work with an interdisciplinary mathematics-science approach based on students exploring phenomena and constructing representations across multiple modes- drawings, tables and graphs. The core of the approach involves the teacher drawing on student representational work to guide the class towards a scientific consensus (Tytler, Prain, Hubber & Waldrip, 2013). In future issues of Let's Find Out we will draw on the 'Ideas for Teaching Science P-8' in further topics, such as exploring animals, supported by examples from our research of students' work.

References

Tytler, R., Ferguson, J., & White, P. (2019). Constructivist and sociocultural theories of learning. In G. Venville & V. Dawson (Eds), The art of teaching science (3rd Ed) (pp. 34-49). Allen and Unwin.

Tytler, R., Peterson, S. & Prain, V. (2006). Picturing evaporation: Learning science literacy through a particle representation. Teaching Science, 52(1), 12-17. (Awarded "most valuable paper" for 2006)

Tytler, R., Haslam, F., Prain, V., & Hubber, P. (2009). An explicit representational focus for teaching and learning about animals in the environment. Teaching Science, 55(4), 21-27.

Tytler, R., Prain, V., Hubber, P., & Waldrip, B. (Eds.). (2013). Constructing representations to learn in science. Sense Publishers.

White, P., Nielsen, W., & Tytler, R. (2020). Slowmation pedagogy in senior science biology. Teaching Science, 66(1), 41-50.