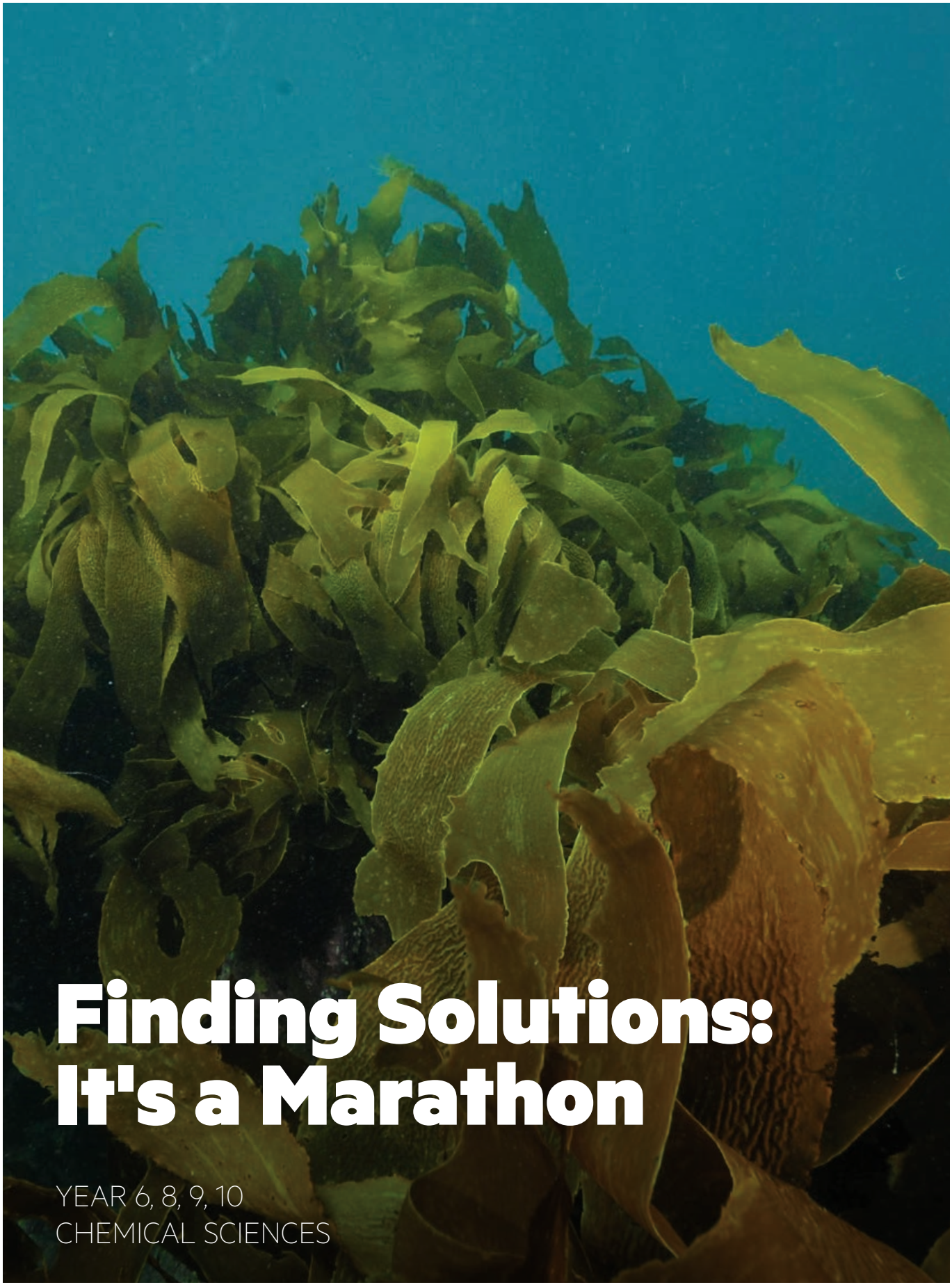


Finding Solutions: It's a Marathon

YEAR 6, 8, 9, 10
CHEMICAL SCIENCES

QGC | FUTUREMAKERS | QUEENSLAND MUSEUM NETWORK | Queensland Government

Future Makers

Future Makers is an innovative partnership between Queensland Museum Network and Shell's QGC business aiming to increase awareness and understanding of the value of science, technology, engineering and maths (STEM) education and skills in Queensland.

This partnership aims to engage and inspire people with the wonder of science, and increase the participation and performance of students in STEM-related subjects and careers — creating a highly capable workforce for the future.

QUEENSLAND MUSEUM NETWORK

Queensland Government

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

This teacher resource is produced by Future Makers, a partnership between Queensland Museum Network and Shell's QGC business, with support from the Australian Research Council and other parties to ARC Linkage Project LP160101374: The University of Queensland, Australian Catholic University Limited and Queensland Department of Education.

ELABORATE - EVALUATE

Finding Solutions: It's a Marathon

Teacher Resource

Scientists, engineers, entrepreneurs, communities and individuals are all investigating ways to reduce the consumption of single use plastics and decrease the amount of waste polluting our environment.

In this activity, students explore an innovative solution to this problem by creating biodegradable and edible water 'bottles' made from brown algae. These edible water bottles, called Ooho, were one of the sustainability solutions implemented during the 2019 London Marathon to reduce the use of over 200,000 plastic water bottles.

You may wish to work through each of the following activities, or choose the parts that are most relevant to your class.

Part 1: Preparing Materials

Instructions for creating sodium alginate and calcium lactate solutions used in the *Edible Water 'Bottle' Experiment*. You may wish to pre-prepare solutions for students, or have the students prepare the solutions in groups.

Part 2: Edible Water 'Bottle' Experiment

Students will create their water 'bottles' using the process of reverse spherification. This process is commonly used in molecular gastronomy to create spheres of juice, preserves or jam. If students are having trouble creating their water 'bottles' you may ask them to add the calcium lactate solution to the sodium alginate and leave the mixture without touching it for 5 minutes, when they can submerge the ice cube for 30 seconds, and then leave it untouched until it has melted completely. Playing with the water 'bottles' while they are forming can cause them to burst, releasing calcium lactate solution into the sodium alginate. When this happens, alginate slime may be formed rather than the 'bottle'.

This experiment can be conducted using different amounts of calcium lactate and sodium alginate, depending on the materials available. Additionally, you may wish to complete the experiment using kitchen equipment rather than science equipment (e.g. cups rather than a 500 ml beaker) if you want to allow students to eat their water 'bottles'. Water 'bottles' should only be consumed if they are made under food-safe conditions, following the safely guidelines of your school.

Part 3: Elements, Compounds and Mixtures (Year 8 Science)

Students analyse the changes that occur throughout the experiment, identifying physical and chemical changes and how these changes impact the properties and arrangement of particles. They will also examine the number of atoms and elements found in one monomer of calcium alginate.

Part 4: Ions and Chemical Reactions (Year 9 Science)

In Part 4, students investigate how ions impact chemical reactions, exploring the impact of calcium chloride and sodium chloride on alginate. Students will conduct an experiment, and then analyse the results with a focus on the charge of calcium and sodium ions.

Part 5: Design Evaluation (Design and Technologies)

In Part 2 of this activity, students created an edible and biodegradable water 'bottle' using sodium alginate from brown algae. In Part 5, students will evaluate the water 'bottles' to determine if they are a viable alternative to plastic water bottles.

Part 6: Future Solutions (Design and Technologies)

In Part 6, students will design an innovative solution to reduce the problem of single-use plastics. You may wish to develop the criteria for success as a class or model how criteria for success may be developed in *Part 5: Design Evaluation*. Students may pitch their ideas to the class and share feedback. You may also wish to submit student design solutions to one of the many environmental/ sustainability design challenges that are scheduled throughout the year.

Curriculum Links

Science

YEAR 6

Science Understanding

Changes to materials can be reversible or irreversible (ACSSU095)

Science as a Human Endeavour

Scientific knowledge is used to solve problems and inform personal and community decisions (ACSHE100)

Science Inquiry Skills

Compare data with predictions and use as evidence in developing explanations (ACSIS221)

Reflect on and suggest improvements to scientific investigations (ACSIS108)

Communicate ideas, explanations and processes using scientific representations in a variety of ways, including multi-modal texts (ACSIS110)

YEAR 8

Science Understanding

Differences between elements, compounds and mixtures can be described at a particle level (ACSSU152)

Properties of the different states of matter can be explained in terms of the motion and arrangement of particles (ACSSU151)

Chemical change involves substances reacting to form new substances (ACSSU225)

Science as a Human Endeavour

Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations (ACSHE135)

People use science understanding and skills in their occupations and these have influenced the development of practices in areas of human activity (ACSHE136)

Science Inquiry Skills

Identify questions and problems that can be investigated scientifically and make predictions based on scientific knowledge (ACSIS139)

Collaboratively and individually plan and conduct a range of investigation types, including fieldwork and experiments, ensuring safety and ethical guidelines are followed (ACSIS140)

Measure and control variables, select equipment appropriate to the task and collect data with accuracy (ACSIS141)

Construct and use a range of representations, including graphs, keys and models to represent and analyse patterns or relationships in data using digital technologies as appropriate (ACSIS144)

Summarise data, from students' own investigations and secondary sources, and use scientific understanding to identify relationships and draw conclusions based on evidence (ACSIS145)

Reflect on scientific investigations including evaluating the quality of the data collected, and identifying improvements (ACSIS146)

Communicate ideas, findings and evidence based solutions to problems using scientific language, and representations, using digital technologies as appropriate (ACSIS148)

YEAR 9

Science Understanding

All matter is made of atoms that are composed of protons, neutrons and electrons; natural radioactivity arises from the decay of nuclei in atoms (ACSSU177)

Chemical reactions involve rearranging atoms to form new substances; during a chemical reaction mass is not created or destroyed (ACSSU178)

Science as a Human Endeavour

Values and needs of contemporary society can influence the focus of scientific research (ACSHE228)

People use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people's lives, including generating new career opportunities (ACSHE160)

Science Inquiry Skills

Formulate questions or hypotheses that can be investigated scientifically (ACSIS164)

Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods (ACSIS165)

Use knowledge of scientific concepts to draw conclusions that are consistent with evidence (ACSIS170)

Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations (ACSIS174)

YEAR 10

Science Understanding

The atomic structure and properties of elements are used to organise them in the Periodic Table (ACSSU186)

Different types of chemical reactions are used to produce a range of products and can occur at different rates (ACSSU187)

Science as a Human Endeavour

People use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people's lives, including generating new career opportunities (ACSHE194)

Values and needs of contemporary society can influence the focus of scientific research (ACSHE230)

Science Inquiry Skills

Formulate questions or hypotheses that can be investigated scientifically (ACSIS198)

Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods (ACSIS199)

Use knowledge of scientific concepts to draw conclusions that are consistent with evidence (ACSIS204)

Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations (ACSIS208)

Design and Technologies

YEAR 5 AND 6

Design and Technologies Knowledge and Understanding

Examine how people in design and technologies occupations address competing considerations, including sustainability in the design of products, services, and environments for current and future use (ACTDEK019)

Investigate characteristics and properties of a range of materials, systems, components, tools and equipment and evaluate the impact of their use (ACTDEK023)

Design and Technologies Processes and Production Skills

Critique needs or opportunities for designing, and investigate materials, components, tools, equipment and processes to achieve intended designed solutions (ACTDEP024)

Generate, develop and communicate design ideas and processes for audiences using appropriate technical terms and graphical representation techniques (ACTDEP025)

Select appropriate materials, components, tools, equipment and techniques and apply safe procedures to make designed solutions (ACTDEP026)

Negotiate criteria for success that include sustainability to evaluate design ideas, processes and solutions (ACTDEP027)

Develop project plans that include consideration of resources when making designed solutions individually and collaboratively (ACTDEP028)

YEAR 7 AND 8

Design and Technologies Knowledge and Understanding

Investigate the ways in which products, services and environments evolve locally, regionally and globally and how competing factors including social, ethical and sustainability considerations are prioritised in the development of technologies and designed solutions for preferred futures (ACTDEK029)

Design and Technologies Processes and Production Skills

Critique needs or opportunities for designing and investigate, analyse and select from a range of materials, components, tools, equipment and processes to develop design ideas (ACTDEP035)

Select and justify choices of materials, components, tools, equipment and techniques to effectively and safely make designed solutions (ACTDEP037)

Independently develop criteria for success to evaluate design ideas, processes and solutions and their sustainability (ACTDEP038)

Use project management processes when working individually and collaboratively to coordinate production of designed solutions (ACTDEP039)

YEAR 9 AND 10

Design and Technologies Knowledge and Understanding

Critically analyse factors, including social, ethical and sustainability considerations, that impact on designed solutions for global preferred futures and the complex design and production processes involved (ACTDEK040)

Explain how products, services and environments evolve with consideration of preferred futures and the impact of emerging technologies on design decisions (ACTDEK041)

Investigate and make judgments on how the characteristics and properties of materials, systems, components, tools and equipment can be combined to create designed solutions (ACTDEK046)

Design and Technologies Processes and Production Skills

Critique needs or opportunities to develop design briefs and investigate and select an increasingly sophisticated range of materials, systems, components, tools and equipment to develop design ideas (ACTDEP048)

Evaluate design ideas, processes and solutions against comprehensive criteria for success recognising the need for sustainability (ACTDEP051)

Work flexibly to effectively and safely test, select, justify and use appropriate technologies and processes to make designed solutions (ACTDEP050)

Develop project plans using digital technologies to plan and manage projects individually and collaboratively taking into consideration time, cost, risk and production processes (ACTDEP052)

Humanities and Social Sciences

YEAR 6

Knowledge and Understanding: Business and Economics

The effect that consumer and financial decisions can have on the individual, the broader community and the environment (ACHASSK150)

How the concept of opportunity cost involves choices about the alternative use of resources and the need to consider trade-offs (ACHASSK149)

Inquiry Skills

Develop appropriate questions to guide an inquiry about people, events, developments, places, systems and challenges (ACHASSI122)

Examine different viewpoints on actions, events, issues and phenomena in the past and present (ACHASSI127)

Evaluate evidence to draw conclusions (ACHASSI129)

Work in groups to generate responses to issues and challenges (ACHASSI130)

Use criteria to make decisions and judgements and consider advantages and disadvantages of preferring one decision over others (ACHASSI131)

Reflect on learning to propose personal and/or collective action in response to an issue or challenge, and predict the probable effects (ACHASSI132)

Present ideas, findings, viewpoints and conclusions in a range of texts and modes that incorporate source materials, digital and non-digital representations and discipline-specific terms and conventions (ACHASSI133)

Geography

YEAR 9

Geographical Knowledge and Understanding

The effects of the production and consumption of goods on places and environments throughout the world and including a country from North-East Asia (ACHGK068)

YEAR 10

Geographical Knowledge and Understanding

Human-induced environmental changes that challenge sustainability (ACHGK070)

Environmental world views of people and their implications for environmental management (ACHGK071)

General Capabilities

Critical and Creative Thinking

Inquiring – identifying, exploring and organising information and ideas

Generating ideas, possibilities and actions

Reflecting on thinking and processes

Analysing, synthesising and evaluating reasoning and procedures

Personal and Social Capability

Self-management

Social awareness

Social management

Ethical Understanding

Understanding ethical concepts and issues

Reasoning in decision making and actions

Exploring values, rights and responsibilities

Cross-Curriculum Priorities

Sustainability

Sustainable patterns of living rely on the interdependence of healthy social, economic and ecological systems. (OI.3)

World views are formed by experiences at personal, local, national and global levels, and are linked to individual and community actions for sustainability. (OI.5)

Actions for a more sustainable future reflect values of care, respect and responsibility, and require us to explore and understand environments. (OI.7)

Designing action for sustainability requires an evaluation of past practices, the assessment of scientific and technological developments, and balanced judgements based on projected future economic, social and environmental impacts. (OI.8)

Sustainable futures result from actions designed to preserve and/or restore the quality and uniqueness of environments. (OI.9)

Finding Solutions: It's a Marathon

Student Activity

Problematic Polymers

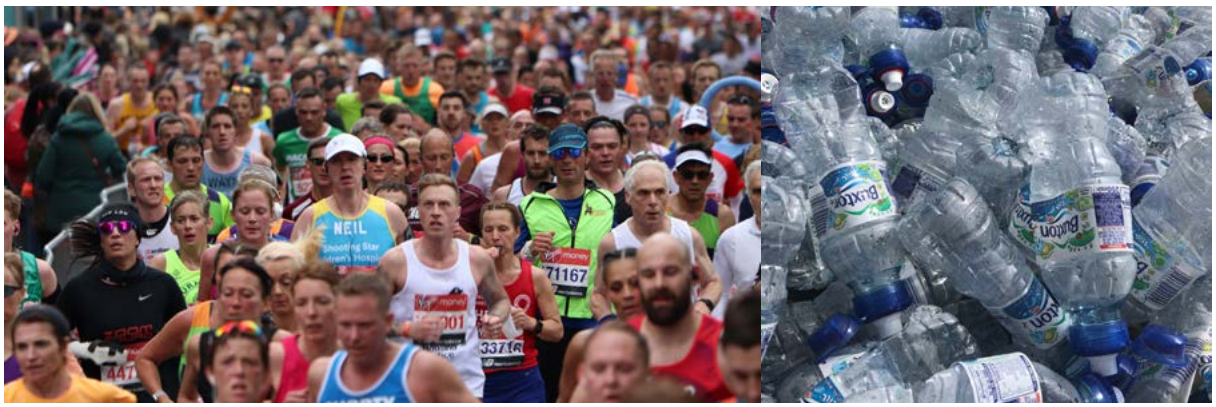
Scientists from Queensland Museum have found plastics in turtles, seabirds, whales, and even on the unexplored ocean floor 4000 m below the water surface. Some of the plastics that we have found can be seen in the *Death by plastics* display in *Wild State*. They have also been displayed through the Hatchery during the World Science Festival Brisbane.

By 2050 it is predicted there will be more plastic than fish in the world's oceans[4], and this is harming our wildlife. Humans purchase over one million plastic bottles per minute. Most of these are not recycled and may end up in landfill or in our oceans where they slowly break down into smaller pieces of plastic and can last hundreds of years.

Plastic pollution is a huge problem that people all over the world are working to solve. Scientists at Queensland Museum are trying to raise awareness of this issue in order to encourage people to reduce their consumption of plastic and to dispose of waste thoughtfully. Other solutions being implemented in Australia are based on policy changes, for example removing free plastic bags from the supermarkets, or public awareness campaigns such as encouraging people to refuse plastic straws, while other groups are working on engineered solutions to our plastic problem.

London Marathon

The London Marathon is one of the largest races worldwide. In 2018, 919,000 plastic bottles were used by participants in the marathon. To reduce the amount of plastic waste created by the London Marathon, many sustainability initiatives were implemented in 2019 to reduce the environmental impact of the marathon. One of these initiatives was a trial of Ooho, edible and biodegradable seaweed capsules filled with sports drink, which were used to replace plastic cups or bottles at one drink station. In total, the number of plastic bottles used in the London Marathon decreased by over 200,000 due to the sustainability initiatives that were enacted between the 2018 and 2019 marathon.



Runners in the London Marathon, and piles of plastic bottles left on the roadside after the marathon.

[4] Neufeld, L., Stassen, F., Sheppard, R., & Gilman, T. (2016). The new plastics economy: rethinking the future of plastics. *In World Economic Forum*.

Polymers and Monomers

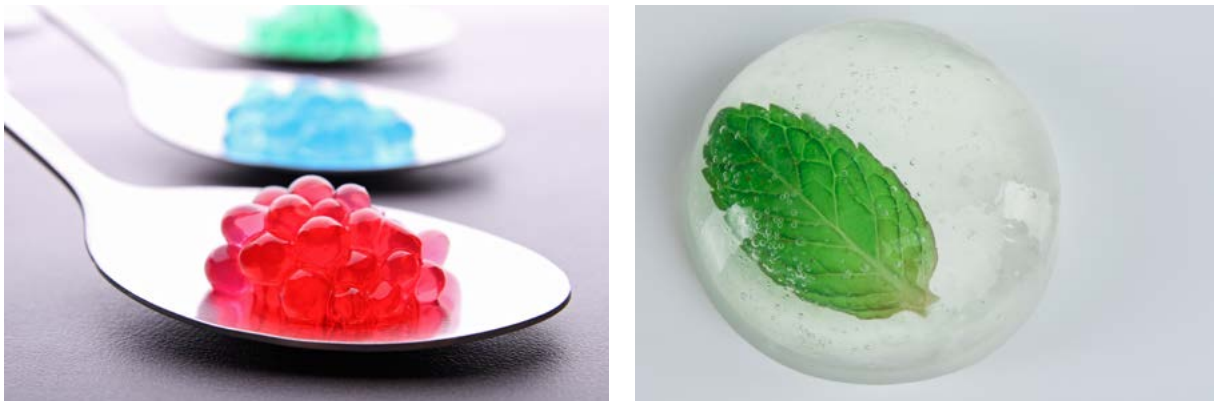
A polymer is a large molecule (macromolecule), made up of many small molecule repeating units (known as monomers). While plastics are environmentally problematic polymers derived from fossil fuels, many polymers occur naturally in the environment and in biological systems (e.g. cotton, starch, silk, wool, natural rubber). Your body is made of some of these polymers, including proteins made of amino acids and your DNA (deoxyribonucleic acid is composed of repeating nucleotides).

Sustainable Seaweed, Amazing Algae

Brown algae (also known as kelp or brown seaweed) is often exposed to rough seas, so it needs to be tough and flexible. The flexibility of brown algae is caused by the presence of the natural polymer sodium alginate in its cell walls.

Brown algae grows in the marine environment, providing habitat and food for other marine organisms. It is tough and flexible to survive rough seas and strong currents.

Brown algae is processed to extract the sodium alginate, which is used commonly to thicken and stabilise food mixtures, such as ice cream, pudding, canned fruit, the pimento strips in green olives and even canned dog food! It is also used in indigestion tablets and for moulding and casting, including in the creation of dental impressions. Sodium alginate is also used in molecular gastronomy, a food science discipline that uses science to create unusual textures and an exciting food experience.



Sodium alginate from brown algae can be used in spherification, where liquids are solidified or gelled into spheres, for example to create spheres of juices or flavoured 'caviar'.

Finding Solutions: It's a Marathon

Part 1: Preparing Materials

Preparing your materials

To complete the edible water bottle experiment you will need to prepare a solution of sodium alginate, and prepare and freeze a solution of calcium lactate.

Materials

1 heaped tbs calcium lactate

1 heaped tbs of alginate

2 L distilled water

1 x blender

1 x 1 L measuring jug

1 x large ice cube tray

6 x ½ cup measurements (approximately, you could use any small container)

Preparing calcium lactate solution

1. Add 1 heaped tablespoon of calcium lactate to 1 litre of water.
2. Use a blender to mix until the calcium lactate has completely dissolved. You may wish to add some food colouring.
3. Pour calcium lactate solution into an ice cube tray and place in a freezer until completely frozen. Pour the remaining calcium lactate solution into ½ cup containers.
4. Place in freezer and leave until frozen through.

Preparing sodium alginate solution

1. Add 1 heaped tablespoon of alginate and 1 L of distilled water into a clean blender. Blend until the alginate has completely dissolved.
2. Pour the alginate solution into a large bowl and leave for 1 hour to eliminate bubbles.

Finding Solutions: It's a Marathon

Part 2: Edible Water 'Bottle' Experiment

Aim

Use chemistry to create a biodegradable and edible water 'bottle'!

Creating Your Water 'Bottle'

Materials

300 mL of sodium alginate solution

Calcium lactate ice cubes

1 x 500 mL beaker

Soup spoon

Slotted spoon

Water

Timer

Method

1. Pour 300 mL of sodium alginate solution into a 500 mL glass beaker.
2. Warm the sodium alginate solution in a microwave for 45 seconds.
3. Gently drop a calcium lactate ice cube into the sodium alginate. Start the timer. After one minute, use your finger to gently submerge the calcium ice cube for 3 seconds. Repeat after every minute, making observations.
4. Once the calcium ice cube has completely melted, use your hand or a slotted spoon to gently remove the water 'bottle' from the alginate solution and place in a bowl of water to rinse. The water 'bottle' is now ready to eat!
5. Repeat steps 1 to 3 with ½ cup frozen calcium lactate solution for an even larger water 'bottle'!

Results

Record your observations.

Draw a diagram or attach a labelled picture of the product.

How did the properties of the materials change throughout the experiment?

Part 3: Elements, Compounds and Mixtures

Draw the arrangement of particles:

a) Before the calcium solution has been placed in the freezer.	b) Immediately after the calcium solution has been removed from the freezer.

Why is a frozen solid calcium solution used for this experiment, rather than a liquid calcium solution? Include information on the properties of matter.

Why is the alginate solution heated before adding the frozen calcium solution? Include information on the properties of matter.

Does a physical or chemical change occur when the calcium lactate ice cube is placed into the sodium alginate? Why?

One of the products in this experiment is calcium alginate. The formula for calcium alginate is $C_{12}H_{14}CaO_{12}$. Explain if this is an element, compound or a mixture.

Record the name and number of each element in $C_{12}H_{14}CaO_{12}$ in the table below.

Element Name	Chemical Symbol	Number of atoms

How many elements are in calcium alginate?

How many atoms are in a monomer of calcium alginate?

Part 4: Ions and Chemical Reactions

In Part 4 of this activity you will investigate how the charge of an ion may impact the chemical reaction.

1. Complete the table below
   a) Use the periodic table to find sodium and calcium.
   b) Draw the structure of the atoms below, showing the protons, neutrons and electrons.
   c) Explain how each atom forms an ion.
   d) Draw the structure and charge of the ion, include protons, neutrons and electrons.

Atom	Sodium	Calcium
Draw the atom		
How does this atom form an ion?		
Draw the ion, including the charge		

2. Sodium can form the ionic compound sodium chloride, while calcium can form calcium chloride. What is an ionic compound, and how are these ionic compounds formed?

Ions and Chemical Reactions

In this experiment you will compare the effect of sodium chloride and calcium chloride on alginate, and identify how ions can impact chemical reactions.

Materials

Sodium alginate solution

2 g sodium chloride (NaCl)

2 g calcium chloride ($CaCl_2$)

200 mL distilled water

2 x 200 mL beaker

2 x plastic pipette

Method

1. Prepare a sodium alginate solution using the instructions in Part 1.
3. Add 2 grams of sodium chloride to 100 mL of distilled water and stir until dissolved. Label the beaker Na^+.
4. Add 2 grams of calcium chloride to 100 mL of distilled water and stir until dissolved. Label the beaker Ca^{2+}.
5. Use a clean pipette to pour a thin stream of alginate into the sodium chloride solution.
   NOTE: Hold the pipette above the sodium and calcium salt solutions; do not dip the end of pipette into the salt solutions.
6. Leave for 3 minutes, record observations and use a slotted spoon to try and remove the alginate from the salt solution.
7. Repeat steps 4 and 5 with the calcium chloride solution.

Variables

Record the variables in the table below.

Independent variable	Dependent variable	Control variables

Hypothesis

Write a hypothesis for the experiment.

Results

Record your observations.

Sodium chloride (NaCl)	Calcium chloride ($CaCl_2$)

Explain what the results found.

Discussion

Explain why these results occurred.

Your answer should include the words in the word bank below.

ion	bonds	chemical reaction	periodic table	electrons	charge

Complete the table below to analyse the chemical reaction.

Unbalanced Equation
$\_\_\_\_ C_6H_7NaO_6 + \_\_\_\_ CaCl_2 \longrightarrow \_\_\_\_ C_{12}H_{14}CaO_{12} + \_\_\_\_ NaCl$
Write the balanced equation below.
Write the word equation below.
Identify reactants and products.

Part 5: Design Evaluation

What are some advantages of this edible water 'bottle'?

Do you think that this is a viable alternative to plastic water bottles? Consider criteria that alternatives would require for successful use.

Can you think of other uses for the water 'bottle'?

How could you improve this design?

Once you have brainstormed design improvements you may wish to make these changes and repeat the experiment, or move to *Part 6: Future Solutions*.

Part 6: Future Solutions

We know that single use plastics pose a major threat to our environment. How can you fix this problem?

In this activity you will design an innovative solution to the world's plastic problem.

You will either develop a solution to:

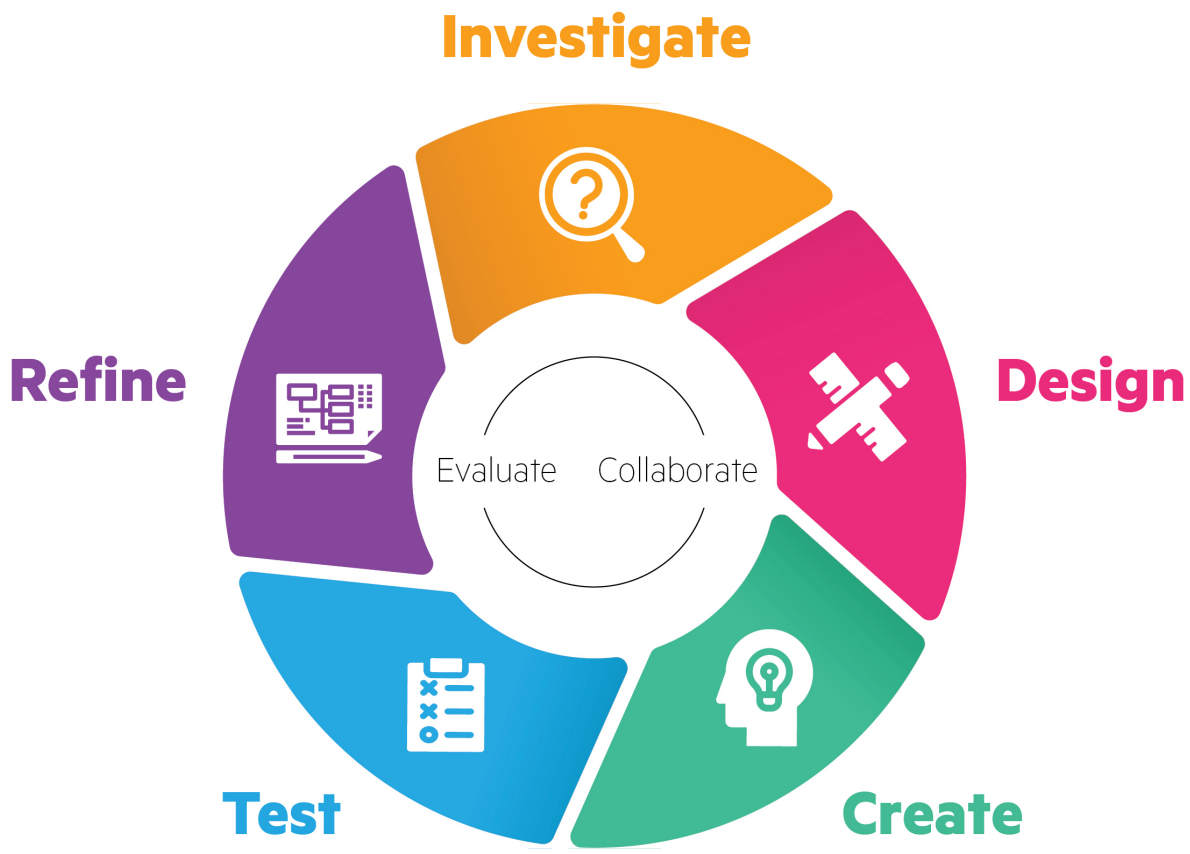
a) Reduce the consumption of single use plastics;

b) Reduce the amount of plastics in our oceans and/or environment;

c) Improve our recycling solutions; or

d) Improve the edible and biodegradable water 'bottle' you made in Part 2 of this activity.

How could you reduce the impact of plastics on our planet?



You will:

- **Investigate** how plastics impact our environment and look at current solutions to improve this problem. Develop criteria that solutions would need to meet to successfully improve our plastic problem (success criteria).
- **Design** an innovative solution to the plastic problem, and develop a project plan to manage the development and implementation of your solution. You should consider success criteria in your design.
- **Create** your design solution.
- **Test** your design solution and evaluate it against the success criteria.
- **Refine** your design solution to better solve the problem and meet the success criteria.
- **Evaluate** the design solution continuously against the success criteria, and make changes to improve the design.
- **Collaborate** with your team members, pitch your design and respond to feedback from other teams.

Appendix 1: Additional Activities

Identifying Nurdles

Nurdles are small plastic pellets about the size of a lentil, used as raw materials to produce nearly all of our plastic products. Countless billion are used each year, but many of these end up washing up on our shores.

An excellent activity involves collecting samples of sand from the beach and having students go through the sand to identify the nurdles. They are hard to find as they discolour over time, however this is a great example to show students that plastic waste washes up everywhere and you often cannot see it.

More information:

- ABC Science – Most plastic on our beaches could have come from anywhere. But not the Durban nurdle.
- COSMOS – Ending the age of plastic
- Nurdle Hunt – Nurdle Free Oceans

Beat the Microbead

Microbeads are a type of microplastic used in cosmetics for scrubbing or exfoliating. These flow straight from the bathroom drain into the sewer system and then the ocean. Students can use this resource to identify common products that contain microbeads.

Beat the Microbead – beatthemicrobead.org

Timeline for Decomposition

Students predict how long common materials take to break down. This can then lead into an interesting class discussion and/or a research task.

Timeline for Decomposition – peacecorps.gov/educators/resources/timeline-decomposition

Conserving Plastics

Although plastic is a big problem in our environment, scientists and conservators are working to prevent the decomposition and loss of significant plastic artefacts in museums and art galleries.

For more information on the conservation of plastics, see the National Geographic article The Race to Save Historic Plastic Artifacts.

In this activity, students can use Queensland Museum Learning Resources to search some of the plastic objects in the Museum collection (choose 'see more search options', the select 'collection item'. Type the search term 'plastic'). Students should choose one plastic object and discuss why the object was collected, and why it is important to conserve.