STUDENT FACT FILE STAGE 5

CHEMICAL ENGINEERING

SOLVING PROBLEMS WITH CHEMISTRY

FROM LAB TO REAL LIFE

What is chemical engineering?

Design. Optimise. Solve.

Chemical engineers help turn raw materials into the products we rely on every day.

Think chemical engineering is all test tubes and beakers? Think again. From food to fuel, and from medicines to clean water, chemical engineers make things happen more efficiently and sustainably.

This is a field that combines science, maths and creativity to tackle some of the world's biggest challenges. Chemical engineering is about understanding exactly how chemicals, like perfume or pesticides or plastic, are made. Turning raw materials into usable products is a complex process with many steps.

Chemical engineers tackle the challenge of optimising those processes. They are problem solvers who link science with real-world applications – and their skills are in demand across Australia and the world.

"I chose chemical engineering because I wanted something where I could solve real-world problems in areas where I can have a big impact. As a chemical engineer, you'll help our world run more sustainably."
– Professor Cordelia Selomulya, Head of School, UNSW Chemical Engineering

This Fact File gives you information on chemical engineering, ideas for how it can be applied, what sort of projects chemical engineers might work on, and a case study of what it's like to work in the job. It also includes a series of classroom activities on chemical engineering linked to the NSW Education Standards Authority (NESA) science syllabus.

Did you know?

Jobs in chemical engineering are predicted to grow by 23% over the next ten years.

Source: Jobs and Skills Australia

Creativity and impact

Think about the future. By 2050, there will be around 10 billion people on Earth. That's a huge challenge. We'll need healthy food, clean energy, safe drinking water and more sustainable ways to live. Chemical engineers are vital to achieving this. They design and adapt the processes that industries and manufacturers use, so we can use less energy, create less waste and deliver more positive impact.

Right now, chemical engineers are in high demand. That's because our world is shifting towards cleaner energy, greener technologies and more sustainable ways of doing almost everything. With skills in water treatment, cleaner manufacturing, battery technology and renewable fuels, chemical engineers will continue to play a major role in building our future.

As a chemical engineer, you'll learn to manage the technical, environmental and financial aspects of major projects. And you'll develop skills in leadership, communication and problem-solving.

If you're curious about how things work, enjoy science, and want to make a real impact, chemical engineering could be a great fit for you. It's a career for people who are future-focused, who want to create more sustainable products and who care about protecting the environment.

What does a chemical engineer do?

Chemical engineers often have incredible careers. At UNSW, chemical engineering graduates have become CEOs of global companies, shaped clean energy strategies and developed new medical technologies.

As a chemical engineer, your job might be to:

- Design and operate large-scale manufacturing plants
- Develop new materials or sustainable products
- Improve processes to make them more environmentally friendly
- Optimise workflows in labs, factories, refineries, or even out in the field

Chemical engineers have career opportunities in many industries. They can work on clean water technologies, renewable energy, sustainable building materials, pharmaceuticals, cosmetics, food and beverage production, air quality management or even sustainable life in space.

The bottom line? Chemical engineers apply their creativity and problem-solving skills to make tomorrow better.

Change the world

Clean Energy:
Chemical engineers are helping Australia transition to net zero by developing renewable fuels like hydrogen, improving battery storage and designing more efficient energy systems. They work on large-scale projects that make wind, solar and biofuels more viable and accessible.
Did you know:
The entire UNSW Sydney campus is fully powered by its own solar tech.

Pharmaceuticals & Biomedical:
From developing new drug formulations, manufacturing vaccines, and designing biomaterials such as soft implants and drug delivery systems, chemical engineers are a vital part of healthcare innovation and large-scale pharmaceutical production.
Did you know:
UNSW researchers have developed a 3D printer that prints with living cells.

Food and Water Security:
From purifying drinking water to designing more efficient food processing systems, chemical engineers help ensure Australians have safe access to clean water and nutritious food. Their work reduces waste and energy use in food production.
Did you know:
UNSW is home to its own Water Research Laboratory, for problem-solving and testing around water quality.

Environmental Sustainability:
Chemical engineers help reduce pollution and waste through cleaner production methods, carbon capture, waste recycling and water treatment. Their designs minimise environmental impact while improving efficiency across industries.
Did you know:
Switching to sustainable aviation fuel could reduce greenhouse gas emissions by around 70% compared to traditional jet fuel.

Chemical engineering lets you know if you should toss those leftovers.

Case Study

Tackling food waste with nanotechnology

When chemical engineer Professor Rona Chandrawati opens her fridge, she sees more than just food. She sees an opportunity to solve one of the world's biggest problems – using tiny molecules.

"We open our fridge, we check the best before stickers, sometimes we end up throwing food out even when it's still safe to consume," explains Rona. This results in over 7.6 million tonnes of food waste every year, according to Foodbank, enough to fill the Melbourne Cricket Ground nine times over. All this waste costs Australians over $36 billion and 17.5 million tonnes of CO_2 every year, even though 70% of this wasted food is still edible.

Rona wants to change all that. She's using nano-scale chemistry to invent new colour-changing best-before sticker technology.

Instead of relying on a printed use-by date, Rona's best-before sticker changes colour when food spoils.

A sticker that can "sniff"

If you've ever smelled rotten fish or off milk, you'll know just how effective your nose can be at sensing spoiled food. These high-tech stickers work in much the same way, Rona says: "The stickers can 'sniff' the molecules inside the food packaging and in real time," says Rona.

When food is fresh, the sticker is blue. When it's spoiled, it turns red. "It's easy to see, easily understandable, cheap and cost-effective," Rona says.

Even better, this chemical engineering solution could help Australian families waste less food, save money and reduce their risk of food poisoning.

"They can respond to spoilage molecules long before the food becomes unsafe to eat"

The chemistry behind the colours

How do the stickers work? Well, Rona leads UNSW's Nanotechnology for Food and Medicine (NanoFAM) Laboratory, so it's no surprise that nanotechnology is very much involved.

Each sticker contains specifically designed sensor polymers that react with the stinky molecules (like ammonia) that food produces as it spoils. These interactions change the polymer's structure and colour. By attaching different functional groups, such as carboxylic acids or amines, to the sensor polymers, Rona can tune how the stickers respond to different molecules released as food spoils.

"It works a bit like acid–base reactions," Rona explains. "For example, ammonia is basic, so when it interacts with acid groups on the polymer, that interaction changes the structure of the polymer's backbone, which causes the colour to change."

By changing the reactivity, Rona can tailor different sensor molecules to react with different foods. "Fish emits different types of molecules compared to meat compared to chicken," she explains.

Because the sensors are made from nanostructured polymers, they have an extremely high surface-area-to-volume ratio. This makes them much more reactive. "It's like dissolving sugar in water," Rona says. "Grains of sugar dissolve much faster than solid sugar cubes because they have a greater surface-area-to-volume ratio.

"Imagine sucking a whole lolly without breaking it, compared to crunching it with your teeth into smaller pieces. The broken lolly dissolves faster in your mouth because there is more surface area for the small volume, so your saliva can work on it more efficiently."

This means Rona's best-before sensors will react to the presence of even tiny levels of spoilage molecules. "That's why we have to work at the nanoscale," she says, "by making the sensors this small, they can respond to spoilage molecules long before the food becomes unsafe to eat."

Beyond food: chemistry for health

Food waste isn't the only challenge Rona is tackling. She also works on nanozymes: tiny particles that mimic enzymes in the human body.

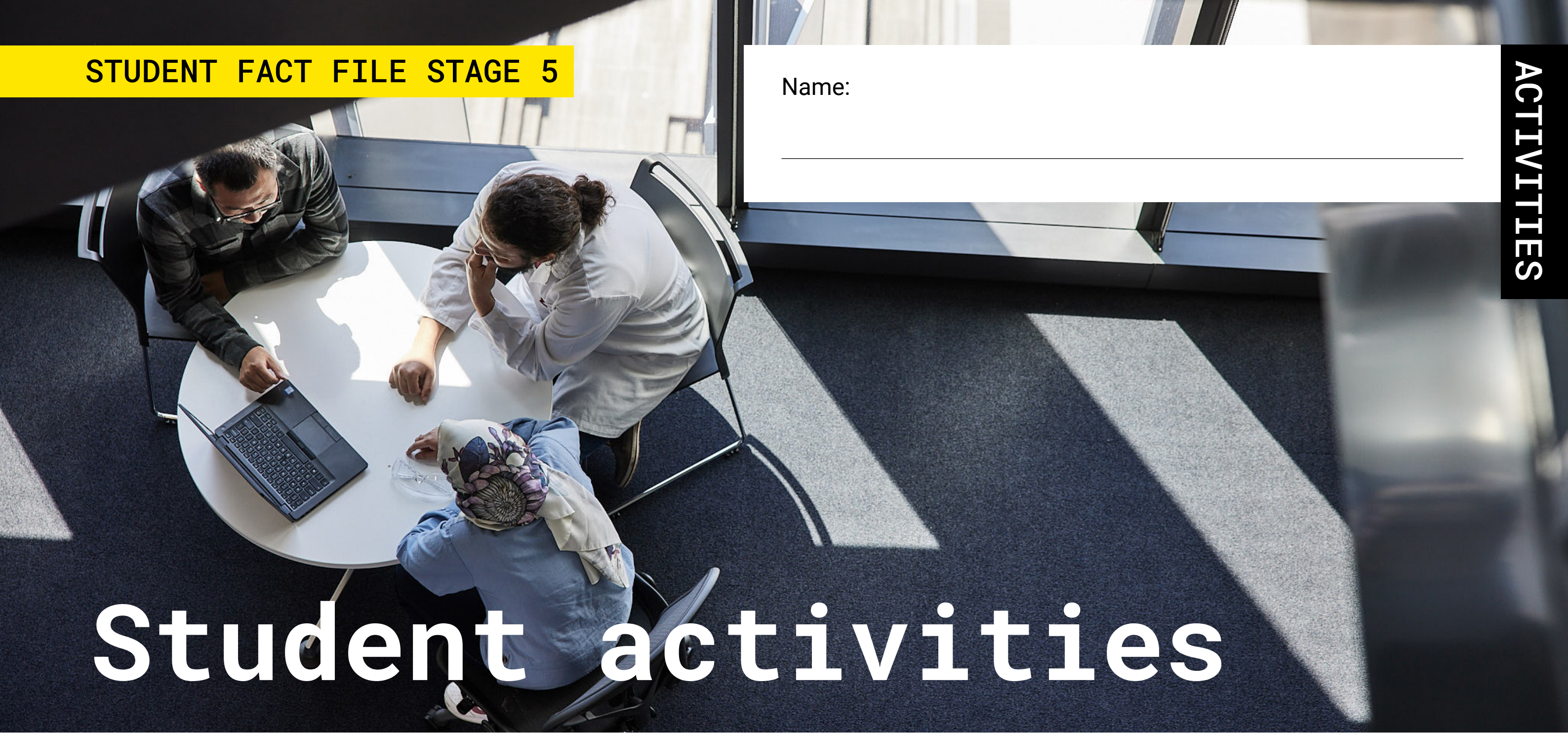
Enzymes are proteins that speed up chemical reactions, but they can be damaged or destroyed at high temperatures. Nanozymes, by contrast, are more robust. Rona is exploring how nanozymes could be used in medicine. For example, they could be used to help the body produce nitric oxide to improve cardiovascular health, or to coat medical implants like stents to prevent bacterial infections.

From classroom to career

Rona says her journey as a chemical engineer began in high school, where she loved chemistry, physics and maths. She remembers being fascinated by "the things you can't really see with your eye but that happen anyway," and wishing she had "a very powerful microscope to see what's happening." Now, she's using super high-tech electron microscopy to watch chemical reactions and materials forming at the nanoscale.

Rona says her chemical engineering skills are the ultimate life hack. "Whether you want your oven to cook faster or the battery of your phone to last longer, engineering, and in particular chemical engineering, can really solve a lot of everyday problems. With chemical engineering, you can make a better world."

Name:



Student activities

Section 1: Literacy: introduction to chemical engineering

Activity 1a: Mind map

Careers in chemical engineering

Read the background article “What is chemical engineering?” and create a mindmap!

1. Read the background information. Highlight the different roles of chemical engineers and what they do.
2. Use the highlighted information to create a mind map to showcase what chemical engineers do. How will you organise the information so that it helps show the jobs and skills of chemical engineers?
3. Conduct some research about chemical engineers and add in some more information, including images and/or symbols.

Activity 1b: Discussion

Understanding sustainability

One of the main roles of chemical engineers is to help the world run more sustainably – by using less energy, creating efficient processes and producing less waste.

Read the background article "What is chemical engineering?", and take part in a class discussion on the following questions. Summarise your ideas in the space provided.

1. Understanding sustainability: What does the term sustainability mean to you? Why is sustainability an important focus for everyone – individuals, communities and industries?

2. Sustainability in products: Pick an object in the classroom. How can we, as users, be more sustainable about it? How could the company that makes it be more sustainable?

3. Living more sustainably: Suggest some ways we can live more sustainably as a society (think about energy, water, transport, plastics, waste and food choices).

4. The role of chemical engineers: How might chemical engineers discover ways for us to live more sustainably?

Activity 1c: Word bank

Define these key terms

Read the article "Tackling food waste with nanotechnology". As you read, create a word bank by writing simple definitions for the following key terms:

Chemical engineer	
Molecules	
Nanoscale	
Polymers	
Functional groups	
Acid–base reactions	
Enzymes	
Nanozymes	
Stents	
Bacterial infection	
Electron microscopy	

Use the article as your starting point, and then check your definitions with a science dictionary or a reliable online source to make sure they're accurate.

Section 2: Applying knowledge through practical activities

Activity 2a: The ocean garbage patch

From plastic waste to recycling

Introduction

Plastic pollution is one of today's biggest environmental challenges. Watch this video bit.ly/48Pboaw on an ocean garbage patch. Chemical engineers design and improve recycling processes, develop new materials that can be reused or broken down safely, and create innovative chemical solutions to reduce waste and pollution.

Aim

- To investigate how different types of plastics can be separated from mixed waste in a simulated ocean garbage patch clean up.
- To explore how basic chemical principles support plastic recycling processes.

Method

Before you start the activity, read through the method and complete the risk assessment at the end.

1. Your teacher will supply an ocean water sample containing plastic. Follow the steps to separate out the plastics.
2. Remove any larger objects and place them to one side.
3. Place the sieve over an empty beaker and pour the water through it to separate out the smaller pieces of plastic. Use a washbottle to get any remaining plastic out of the first beaker. Put the plastic into a separate container.
4. Use the filter funnel and filter paper to filter the water of the smallest fragments of waste. When you're finished, put the filtered waste in a container.
5. Using tweezers, try to sort the waste into small groups where each group contains the same type of plastic. Describe each type of plastic in the results table.
6. Use the Resin Identification Codes shown below to sort the plastics into the 7 different types.

Resin Identification Codes (RICs)

1 (PET/PETE): Polyethylene terephthalate, used for water bottles, soft drink containers, and food jars.

2 (HDPE): High-density polyethylene, used for milk jugs, shampoo bottles, and some plastic bags.

3 (PVC): Polyvinyl chloride, used for window frames, pipes, and some containers.

4 (LDPE): Low-density polyethylene, found in grocery bags, cling film, and squeeze bottles.

5 (PP): Polypropylene, used for dairy containers, medicine bottles, and bottle caps.

6 (PS): Polystyrene, often found in foam packaging or rigid containers.

7 (Other): A catch-all for other plastics, including some bioplastics, which are often made of mixed materials and can be difficult to recycle.

Risk assessment

Complete the following risk assessment before you start this activity.

Hazard	Risk	Mitigation
Spilt water on the floor	Slipping causing injury	
Sharp edges of plastic	Possible cuts	

Results

Type of plastic	Description of plastic	How to dispose of this type of plastic

Discussion

1. Some plastics can be recycled by being melted and remoulded into new products. This process is known as **mechanical recycling**. Research and describe the mechanical recycling process used by one organisation or facility in Australia. Outline the main steps involved in turning waste plastic into new material or products. Then identify which of the 7 types of plastic these chemical recycling methods can be applied to. Present your findings any way you like, such as a report, brochure or website.

2. The **chemical recycling** process breaks plastics down into smaller molecules, such as monomers, using processes like pyrolysis and depolymerisation. Research and explain the difference between pyrolysis and depolymerisation, including how each process breaks down plastic. Then identify which of the 7 types of plastic these chemical recycling methods can be applied to. Present your findings any way you like, such as a report, brochure or website.

3. Would mechanical recycling or chemical recycling be effective on the materials you recovered? Can you now recycle everything, or do you still have some unrecyclable rubbish? Put your answers in the results table. Justify your response below using your research from Question 1 and 2, as well as your experience sorting the different types of plastic from the model ocean cleanup.

4. Reflect on the very small particles, micro and nanoplastics that you may not be able to see in the filtered water. What could be done to separate these invisible plastics?

5. For each of the different types of waste you separated, suggest how it could be reused or recycled. Are any of your samples contaminated with different plastics or other materials? How will that affect recycling?

6. How successful were you at modelling the clean up of an ocean garbage patch? Note some strengths and limitations of this model as you write your response.

Conclusion

Write a sentence to 1) summarise how different types of plastic can be separated, and 2) how your understanding of basic chemical principles supports effective plastic recycling processes.

Connection to chemical engineering

Chemical engineers are at the forefront of creating sustainable recycling systems, developing new polymer technologies, and finding ways to turn waste plastics into valuable resources. Their job isn't just discovering chemical reactions, it's designing entire processes and systems.

Section 2: Applying knowledge through practical activities

Activity 2b: Investigating a biopolymer

Solving real world problems with polymers

Introduction

Chemical engineers use both synthetic and natural polymers to solve real problems, from biodegradable plastics to medical gels. In this investigation, you will work with alginate, a biopolymer from brown seaweeds such as kelp.

Alginate ions tend to join together into long chains. Sodium alginate dissolves in water because sodium ions help the long chains spread out, but when alginate meets certain metal ions it forms an insoluble gel. These ions create cross links between the chains, producing a stable network used in wound dressings, drug delivery, water purification and even food science.

Aim

To investigate which metal ion will create the thickest/strongest consistency bio-gel from alginate.

Method

1. Use a measuring cylinder to add 50 mL of the sodium alginate solution to 4 smaller beakers.
2. Use a clean measuring cylinder to add 10 mL of 0.1 M potassium chloride solution into the first beaker and stir. Label this beaker "potassium".
3. Record visible and texture observations in the table below.
4. Repeat steps 2-3, replacing the potassium chloride with 0.1 M magnesium nitrate, calcium chloride and aluminium chloride and using a fresh beaker of sodium alginate each time.
5. Quantitative analysis: gently hold a marble on the surface of the first of your gels. Release the marble and immediately start the stopwatch. Stop timing when the marble reaches the bottom of the beaker, or if it reaches 2 minutes. Record results in the table below.
6. Repeat step 5 for the remaining 3 gels.

Risk assessment

Complete the following risk assessment before you start this activity.

Hazard	Risk	Mitigation
Sharp broken glass	Possible cuts	
Aluminium chloride	Skin and eye irritant	

Results

Cation	Observations	Time taken (s)
Potassium		
Calcium		
Magnesium		
Aluminium		

Discussion

1. Identify the charge on each of the cations tested and write their ion symbol.

2. Were there any trends in your observations of the gels related to the charge of the ions? Describe any trends you can see.

3. In the introduction, you learned that alginate forms a gel when the metal ion forms strong bonds between the acid chains. Referring to this information, explain the trend you described in question 2.

4. Look at your quantitative results table. Which cation produced the thickest/most viscous gel? How do you know?

5. Chemical engineers use alginates in products. Wound dressings need to be soft – which cation best suits this role? Slow-release drug capsules need to be tough – which cation is best here? Use data to justify your responses.

6. Conduct some further research into the uses of alginate compounds as wound dressings. What important properties would a chemical engineer have to take into consideration when developing compounds for use on or in the human body?

7. Imagine you run a large pharmaceutical company and you want to sell drug capsules made from sodium alginate. How would you change the method in this investigation? You might consider: reactants, energy use, waste disposal, equipment requirements and profitability.

Conclusion

Summarise your findings, identifying which metal ion produced the strongest bio-gel and explaining why.

Connection to chemical engineering

This activity models how chemical engineers design and optimise materials at the molecular level. By understanding how different ions affect the structure and properties of biopolymers, engineers can create sustainable, high-performance materials used in medicine, food technology and environmental applications.

Section 2: Applying knowledge through practical activities

Activity 2c: Nanostickers to test for food spoilage

Testing for safe food

Introduction

Read the case study "Tackling food waste using nanotechnology", which talks about using colour-changing stickers to help test for food spoilage. If food is beyond its best before date but remains safe to eat, it does not need to be thrown out and end up in landfill. Using stickers to show that food is not spoiled can help reduce food waste.

Aim

Model how a colour-changing sticker in food packaging can indicate changes in chemistry as food ages.

Method

Before you start the activity, read through the method and complete the risk assessment at the end.

In this activity, you will compare fresh food samples (controls) with the same foods that have been prepared to model food close to or past its expiry/use-by date (test) to see if their chemistry has changed. Note that no particular measurement is good or bad – it's a change in results that indicates a problem with the food. For each food type, test both the control and the test sample with purple litmus paper.

1. For one "control" food sample (e.g., banana control), collect a small amount on a clean watch glass. If the food is solid, add a little distilled water and use a spoon to make a paste before continuing.
2. Using a small strip of purple litmus paper, place it across the food sample for 2-3 seconds and record the colour in the second column of the results table below.
3. For the corresponding "test" food sample (e.g., banana test), record the use-by-date in the third column of the results table.
4. Repeat steps 1 and 2 with a clean watchglass for the "test" food sample (e.g., banana test) and record the colour of the litmus paper in the fourth column of the results table.
5. Compare the two strips side-by-side and fill out the last two columns of the results table confirming whether the test food sample litmus paper has changed and whether you would keep it or not.
6. Clean the watchglasses and repeat steps 1-5 for all other food samples.
7. Once all groups are finished with the experiment, share results as a classroom, and discuss which samples you think were spoiled.

Risk assessment

Complete the following risk assessment before you start this activity.

Hazard	Risk	Mitigation
Sharp broken glass	Possible cuts	
Contaminated food samples		Do not eat any of the food samples
	Food allergies	

Results

Food	Litmus paper colour (control)	Use-by-date (dd/mm/yy)	Litmus paper colour (test)	Control and test same colour?	Keep or throw?

Discussion

1. Which "test" food samples did you conclude to throw away? Did you reduce waste compared to just using the use by date?

2. What do you think is more important: minimising food waste or increasing food safety?

3. What variables did you keep the same across your tests (e.g., sample size, contact time, wetting) and why is that important for a fair comparison?

4. Rona actually designed many different stickers that are tuned to specific molecules for different foods. Why do you think this might be?

5. If you had to place a real sticker inside a sealed food pack, where would you put it? Would it be easy to see? Would it get chemical signals easily? What might happen if the package wasn't properly sealed?

6. Can you think of anyone who wouldn't find colour-changing stickers easy to use? Could you think of a way to fix this problem?

7. If you could interview Rona about her research, what questions would you ask?

Conclusion

How does this activity demonstrate the way a simple colour indicator can help detect chemical changes in food, guide safer low-waste decisions, and model how smart freshness stickers might work in real products?

Connection to chemical engineering

Chemical engineers are turning this principle into real products. They pick the best chemicals to monitor (e.g. amines in fish) and appropriate thresholds for food safety. They select food-safe indicators and films and model how the chemicals spread to make sure they will reach the sticker quickly enough. They tune reactions so the colour change is quick and easy to see, integrate stickers on packaging lines with in-process quality control, and ensure regulatory compliance and sustainability. This demonstration shows the concept while chemical engineering makes it selective, reliable and scalable while reducing waste and protecting safety.

Section 3: Depth Study

Activity 3: Creating and testing bioprinting materials

Solve the organ donation crisis with 3D printing

Introduction

Around the world, thousands of people are waiting for organ donations. To help meet this demand, chemical engineers are developing new 3D bioprinting materials that could one day create replacement tissues and organs. Chemical product engineers design materials with specific chemical and physical properties. It takes creativity and scientific skill to take tantalising ideas like 3D printed organs and solve them with real chemicals and processes.

Aim

To design and test a functionalised liquid biomaterial for a simple 3D bioprinting simulation by investigating how its properties affect its ability to form stable structures when extruded, applying chemical engineering principles to create a material with a specific function.

Summary for this depth study

You will work through the following 5 stages:

1. Conduct some **background research** to help understand what bioprinting is. Make notes from your research that can be used to write an introduction to your final report. Build a reference list as you go.
2. Decide on a **research question** that tests one performance feature (dependent variable) of a quality of the liquid material (independent variable) that can be pushed through a thin nozzle. For example: Can a more viscous liquid hold its shape better than a less viscous liquid? Or does the nozzle size affect the drying time of the biomaterial? Write a **hypothesis** for your investigation.
3. Use clinically safe materials to design and prepare a recipe for your liquid biomaterial in order to **investigate** it using the scientific process. Design a fair test with repetitions and write a risk assessment.
4. Collect quantitative data and then write your **results** up in a full scientific report.
5. Use the **marking rubric** as a check grid.

This depth study is intended to focus on extrusion bioprinting, but if you want to investigate other forms of bioprinting, discuss with your teacher.

Details for this depth study

1. Background research

What is bioprinting and what is it used for? What is a biomaterial? Use the following questions and resources, and some of your own to learn more about 3D printing using living cells.

- UNSW: Bio printing bone bit.ly/3YhaWg6 (1 min)
- TED-Ed: How to 3D print human tissue bit.ly/48uDR6t (5 mins)
- Emerging tech unpacked: Bio printing extension bit.ly/4pnqNps (50 mins)

2. Research question and hypothesis

Research question: Have a think about the variable you would like to manipulate and the variable you would like to measure. Use these ideas to form a draft research question. You can refine this question as your research continues during the course of the depth study if you need to.

Variables: Below is a list of possible variables you can use as you design a research question.

1. Possible variable to manipulate (independent variable): Pressure or speed of delivery of material, nozzle size, concentration of thickener, recipe of biomaterial (change one ingredient only), any variable of your choice approved by your teacher.
2. Possible variable to measure (dependent variable): Drying time, how well the shape is held (shape fidelity can be measured by comparing nozzle size with line width once the gel is extruded), ease of pouring, any variable of your choice approved by your teacher.
3. Variables to control: Which variables will need to be kept the same? For example, room temperature, light levels, size and shape of extrusion. List the variables that need to be controlled.

3. The investigation

After completing your research, design a simple 3D bioprinter analogue. You will need:

- a liquid "bio-ink" to print with
  - Your material needs to be foodsafe, and it needs to be the right consistency. Examples include flour and water, xanthan gum gels and gelatin–glycerol mixtures. For a more complicated material, consider the reaction between calcium chloride and sodium alginate.
- an extruder or tool to squeeze out the liquid
  - Your extruder needs a narrow nozzle, a few millimetres across. Good examples include a syringe, a piping bag or a plastic bag with a small hole cut out of the corner. (Safety note: sharps can be dangerous – where possible, use syringes that are not designed to pierce skin.)
- a surface or material to print onto.

You do not need to build a full 3D printer – manually extruding the bio-ink is enough to model how the printing process works. Once you have materials and a plan ready:

1. Make a sample of your biomaterial and load it into your extruder. Make sure your printing surface is nearby.
2. Carry out your investigation to test one feature by extruding shapes onto the printing surface. Collect both qualitative and quantitative data.
3. Make a list of the materials and equipment used, the method carried out, complete a risk assessment and record all data in a data table. Plot quantitative data on a graph.

Before you start, write a risk assessment for the investigation.

4. Results

Carry out the investigation collecting quantitative data over at least 3 trials.
Visually display data in a graph. Assess your method for validity, reliability and accuracy.

Outcome: Scientific report: Write up the background research, research question, aim, hypothesis, risk assessment, method and results section into a full scientific report. Add a discussion section to assess the validity, reliability and accuracy of your data. Finish off by including a conclusion that responds to the aim and hypothesis. Complete a bibliography using the APA referencing style.

5. Marking rubric

Criteria	**3 marks**	**2 marks**	**1 mark**
Background research	The background research is extensive and appropriately detailed. It enhances the understanding of bioprinting in the context of the investigation.	The background information is mainly appropriate and aids the understanding of bioprinting in the context of the investigation.	The background information is superficial OR of limited relevance and does not aid the understanding of bioprinting in the context of the investigation.
Development of research question, aim and hypothesis	Developed a relevant research question, aim and hypothesis that are strongly linked to the background research and are able to be investigated scientifically through the extensive collection of primary data. Both experimental variables appear with clarity.	Developed a research question and/or an aim and hypothesis linked to background research and are able to be investigated scientifically through the collection of primary data, and considers both experimental variables.	Simple research question aim and/or hypothesis stated poorly. Not well-linked to background research. Experimental variables not clear.
Method	Method is logical, valid, easy to follow and highly suitable for the investigation. Single independent variable clearly set up and detail given for measuring the dependent variable. Repetitions are included. An appropriate risk assessment is completed.	Method is easy to follow but could be adjusted to better suit the investigation. Some detail related to setting up and/or measuring variables, repetitions and risk assessment are missing.	Method is difficult to follow and/or is missing significant detail.
Results	Data is synthesised into a well-designed table and graphs so that a valid conclusion can be made. Included qualitative and quantitative data.	Data is presented in an appropriate table and graph, with some elements missing. Included qualitative and/or quantitative data.	Some basic data is presented, but is too inaccurate or incomplete to draw valid conclusions.
Discussion	A statement of results identifies valid trends in the data. Extensive assessment of validity, reliability, and accuracy.	Trends identified, but missing detail. Basic assessment of validity, reliability and accuracy OR missing one of the three.	Brief discussion missing important trends and/or missing validity, reliability or accuracy.
Conclusion		Strong, valid conclusion relating to the research question, aim and hypothesis.	Makes a basic conclusion that does not link well to the research question.
Reference list		Correct APA format.	Correct APA format with minor errors.
Overall consistency and coherence	Outstanding and well-structured report with each section demonstrating consistency and coherence.	A solid report with all sections present, but lacks some consistency and/or coherence.	Basic report missing some sections and lacking consistency and coherence.

Teacher notes

Section 2: Applying knowledge through practical activities

Activity 2a: The ocean garbage patch

From plastic waste to recycling

Purpose and scope

Students separate plastics from a simulated ocean garbage patch on size and on plastic type using a key. They then consider how each type of plastic might be recycled and conduct some research on both mechanical and chemical recycling methods.

Key idea for students

Plastic waste is an environmental issue that can be alleviated using various collection, sorting and recycling processes. Proper disposal of plastics in the first instance can help reduce the plastic found in the oceans and other waterways. Different councils have different procedures for collecting and recycling plastics.

What to prepare

Seawater sample pre-prepared for each group with different plastics as per the following materials list. The exact plastics don't matter, but it's important to have some larger pieces and some small plastic pieces that need to be filtered out.

- 200 mL beaker with 200 mL of water
- 2-3 postage-stamp sized pieces of plastic bottle
- 5 mL polystyrene beads (could be obtained from styrofoam or insulation products)
- 1 mL non-biodegradable glitter
- Bottle caps, bread clips and other small pieces of plastic, some of it should be ground up with a blender
- 5 g sodium chloride (optional)
- 5 g of sand or sandy soil
- Synthetic clothes fibers/lints from a domestic dryer

Equipment for each group

- Extra 200 mL beaker to catch the water after filtering.
- About 3 shallow containers such as petri dishes for sorting plastics
- Tweezers
- Tea strainer or similar coarse filter
- Washbottle
- Fast filter paper
- Filter funnel

Students will also need computers to research the first two questions.

Safety, risk and disposal

- Add the chemicals and equipment above into riskassess.com.au or other risk assessment record system before doing this activity.
- Ensure any additions or changes are reflected in your student Risk Assessment table.
- PPE: Safety glasses, gloves.
- Slips/spills: wipe immediately. Solutions can be disposed of down sink in a stream of running water.
- Disposal: water can be safely poured down the drain. Dispose of plastic and filter paper in general waste.

Troubleshooting and tips

- Paper towels may be needed to clean up water spillages.
- It will be helpful for students if the plastic triangle identifier is on some of the samples to help sort them.

Activity 2b: Investigating a biopolymer

Solving real world problems with polymers

Purpose and scope

Students use a compound derived from a natural substance to create a biopolymer. They explore the scientific process by testing different cations and using criteria to determine which produced the best gel. This gives students insight into the role of chemical engineers in creating new materials and testing different reagents to achieve desired results.

Key idea for students

Scientists go through numerous testing processes to achieve the desired results. Not all tests are successful, but we are still able to learn something from those that do not work.

Chemical engineers use a scientific approach to synthesise new materials and often take inspiration from nature.

What to prepare

The sodium alginate solution will need to be prepared in advance and left overnight to form a gel with uniform consistency. Method: For each group, dissolve 2 g of sodium alginate powder in 300 mL of water and immersion blend for 5 minutes. Leave covered overnight.

Equipment for each group

- 4 x 100 mL beakers
- 100 mL measuring cylinder
- 10 mL measuring cylinder
- Marker
- Pipettes
- 4x marbles
- Stopwatch
- 0.1M solutions of:
  - Potassium chloride
  - Magnesium nitrate
  - Calcium chloride
  - Aluminium chloride

Safety, risk and disposal

- Add the chemicals and equipment above into riskassess.com.au or other risk assessment record system before doing this activity.
- Ensure any additions or changes are reflected in your student Risk Assessment table.
- Aluminium chloride: skin and eye irritant.
- PPE: Safety glasses, lab coat, gloves.
- Slips/spills: wipe immediately.
- Disposal: solutions can be disposed of down sink in a stream of running water. Solid gels can be disposed of in general waste.

Activity 2c: Nanostickers to test for food spoilage

Testing for safe food

Purpose and scope

Students model a colour-changing packaging sticker using purple litmus paper. They investigate how chemistry in the food can shift an indicator's colour and learn why real freshness stickers are tuned to specific spoilage molecules rather than generic pH.

Key idea for students

A sensor is any material/device that changes in a measurable way when a target is present. Our litmus "sticker" isn't a safety test, it simply shows that since the chemistry changes, the indicator changes. Real stickers are tuned to specific targets (e.g., ammonia, CO_2, etc.).

What to prepare

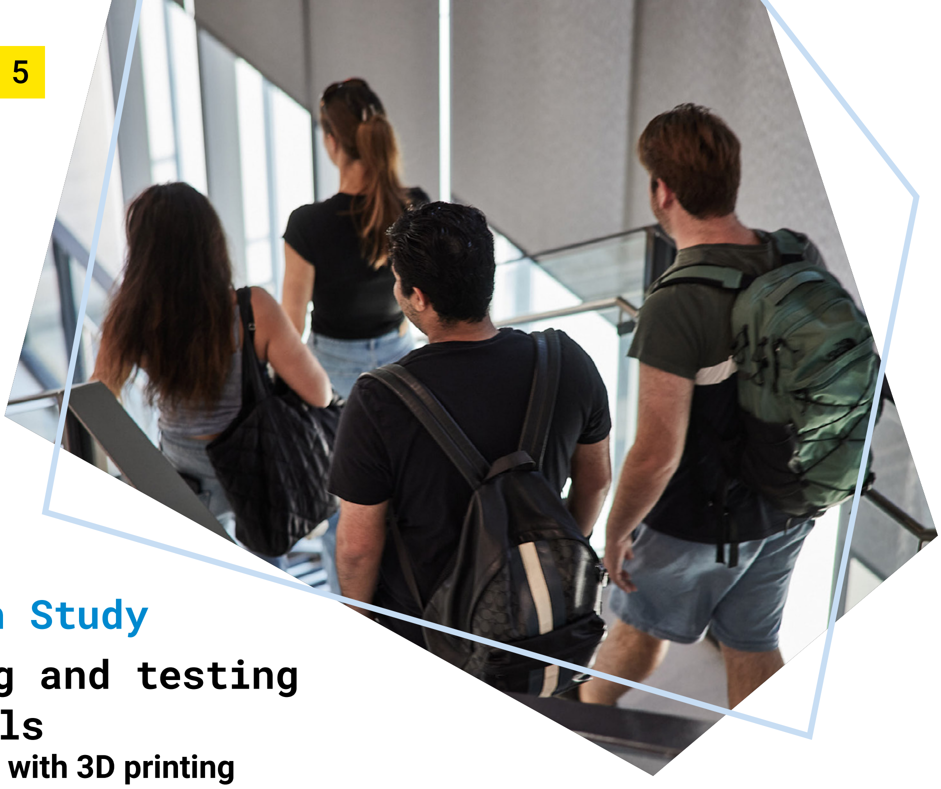
1. For each food, prepare a control sample and label appropriately.
2. For each food, decide whether it is in date, out of date and safe, or out of date and unsafe.
   a. If in date, prepare a sample and label with an in-date used by date.
   b. If it is out of date and safe, prepare a sample and label with an out-of-date used by date.
   c. If it is out of date and unsafe, prepare a sample and label with an out of date used by date. Then spike the sample so it tests differently to the control.
   Some suggested foods and spikes:
      i. Milk → add lemon juice
      ii. Tofu → add bicarb solution
      iii. Banana → add lemon juice
      iv. Apple → add bicarb solution
      v. Bread → add lemon juice
3. It is not recommended that actual spoiled food samples are used in the classroom due to safety issues.
4. Each student or group of students is supplied with unspoiled food samples and spoiled food samples. Alternately, students can come up to the front to take small parts of the prepared samples.
5. Additionally, each group is supplied with 2 watchglasses, distilled water for cleaning, purple litmus paper and a spoon or spatula to mix the food.

Safety, risk and disposal

- Add the chemicals and equipment above into riskassess.com.au or other risk assessment record system before doing this activity.
- Ensure any additions or changes are reflected in your student Risk Assessment table.
- Allergens: milk, soy, etc. (Allow groups to skip any samples that pose a risk to them.)
- Food is for the lab only. Do not taste/eat any sample.
- PPE: safety glasses, gloves, lab coat.
- Slips/spills: wipe immediately.
- Disposal: dispose of samples in general waste. Pour small liquid residues to sink with plenty of water.

Troubleshooting and tips

- A test-run lab demonstration should be done prior to ensure food spiking is done correctly and safely.
- Students should compare against the fresh control of the same food.



Section 3: Depth Study

Activity 3: Creating and testing bioprinting materials

Solve the organ donation crisis with 3D printing

Purpose and scope

Students learn the skills to design, conduct and write up a scientific investigation related to the use of biogels in bioprinting.

Key idea for students

Students learn the process of scientific investigation first hand as they develop organisational skills.

What to prepare

Students are encouraged to source their own gels and nozzles to use for this investigation. Discuss with students to find out what equipment they might need.

As a baseline, consider preparing:

- A few biogel options such as flour and water, xanthan gum and seedless jam.
- Some options for extruding such as syringes with nozzles, small piping bags and ziplock bags with one corner cut off.
- Trays for students to extrude onto
- Measurement tools including rulers, stopwatches, thermometers and small masses such as marbles.

Safety, risk and disposal

- Discuss with students about any equipment or materials that they source for themselves before you let them use it. Possible risks include hypodermic sharps and hazardous chemicals.

Suggested biogel recipes

- 1 part flour, 5 parts water – heat until thickens
- 2 tablespoons cornstarch, 1 cup cold water – mix on medium heat until thickens
- 1 tablespoon xanthum gum, 2 cups water
- 40 mL glycerin, 40 mL water, 7 g gelatin
- 10g agar, 1 L water

Curriculum link chart

Activity	Curriculum Link
Background information + Case Study + Section 1 – Introduction to Chemical engineering	SC5-MAT-01, SC5-ENV-01, SC5-RXN-01, SC5-RXN-02, SC5-WS-08, SC5-WS-05
Section 2a. Ocean garbage patch	SC5-MAT-01, SC5-ENV-01, SC5-RXN-01, SC5-RXN-02, SC5-WS-01, SC5-WS-04, SC5-WS-06, SC5-WS-07, SC5-WS-08
Section 2b. Investigating a biopolymer	SC5-MAT-01, SC5-RXN-01, SC5-RXN-02, SC5-WS-01, SC5-WS-04, SC5-WS-05, SC5-WS-06, SC5-WS-07, SC5-WS-08
Section 2c. Nanostickers to test for food spoilage	SC5-MAT-01, SC5-RXN-01, SC5-WS-01, SC5-WS-02, SC5-WS-04, SC5-WS-05, SC5-WS-06, SC5-WS-07, SC5-WS-08
Section 3 - Depth study: Creating and testing bioinks	All of the Working Scientifically outcomes from SC5-WS-01 to SC5-WS-08

Published by Refraction Media
Publisher: Karen Taylor-Brown
Editor: David Shaw
Writers: Sally Parker, Madeline Carr, Cristy Burne
Subject Matter Expert: Professor Pierre Le Clech
Designed by Jon Wolfgang Miller

Produced on behalf of the UNSW School of Chemical Engineering