



Investigate and Innovate with CSIRO

Thermal Energy Storage

My name:	
My team:	
Our focus question:	

Student workbook and resources



Acknowledgement of Country

CSIRO acknowledges the Traditional Owners of the lands, seas and waters of the area that we live and work on across Australia. We acknowledge all Aboriginal and Torres Strait Islander peoples and their continuing connection to their culture and pay our respects to Elders past and present. CSIRO is committed to reconciliation and recognises that Aboriginal and Torres Strait Islander peoples have made contributions to all aspects of Australian life including culture, economy and science.



'Eternal Wisdom,
Infinite Innovation'
artwork by Rachael Sarra, working
with Gilimbaa.

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Student reference sheet

The Australian Academy of Science [Launch, Inquire, Act \(LIA\) framework](#) helps us structure scientific investigations so that students:

- **Launch** by exploring and connecting to real-world phenomena,
- **Inquire** by investigating and analysing questions, and
- **Act** by applying, communicating and reflecting on our findings.

It's a way to learn science like real scientists do!

PHASE 1: LAUNCH	<p>Purpose: get curious, connect to the world, and ask a great question.</p> <p>What you'll do: Explore a phenomenon or scenario. Think about your own experience and ask: "What's going on here?". Identify what you already know and what you wonder about. Discuss why the topic matters.</p> <p>Key questions:</p> <ul style="list-style-type: none"> • What do I see or experience? • What might be happening? • Why is this important? 	 <p>Launch</p>
PHASE 2: INQUIRE	<p>Purpose: design and carry out an investigation to answer your question.</p> <p>What you'll do: Formulate a testable question. Plan your investigation: decide variables, controls, method. Collect data (measure, record, repeat). Graph and analyse results to spot trends or patterns.</p> <p>Key questions:</p> <ul style="list-style-type: none"> • What variables will I change, and what will I measure? • How will I make it fair? • What do my results show? 	 <p>Inquire</p>
PHASE 3: ACT	<p>Purpose: use your findings to communicate, reflect, and apply to the real world.</p> <p>What you'll do: Draw conclusions based on your evidence. Reflect on your method: what worked, what could you improve? Apply your understanding: how does your investigation link to real-life scientific research or technology? Share your findings through a poster, presentation, or video.</p> <p>Key questions:</p> <ul style="list-style-type: none"> • What did I learn and why does it matter? • How could I do better next time? • How can this knowledge be used in the real world? 	 <p>Act</p>

Icons:

Throughout the investigation you will see these icons (below) to highlight the type of activity and guidance recommended.





About thermal energy storage



What do you know about thermal energy storage? Write the first thing that comes to mind to complete the sentence starter for each box below.

This topic is about...

•

My initial thoughts...

•

What I already know about this topic...

•



Pre and post assessment



What do you know about thermal energy storage? Answer the following questions at the start of your investigation and re-attempt at the end.

Question	Attempt 1	Attempt 2
What type of energy can sunlight be converted into?	<ul style="list-style-type: none">	<ul style="list-style-type: none">
How long do you think each form of energy can be stored?	<ul style="list-style-type: none">	<ul style="list-style-type: none">
Why is thermal energy storage essential for renewable energy?	<ul style="list-style-type: none">	<ul style="list-style-type: none">
What materials might best absorb and release heat?	<ul style="list-style-type: none">	<ul style="list-style-type: none">

Thermal energy storage labelling



Word Bank

- Heliostat
- Actuator
- Solar tower
- Solar trough
- Supercritical steam pipes
- Radiation
- Reflect
- Receiver
- Thermal energy.



Figure 1 Solar thermal heliostat field and tower at CSIRO's solar thermal research facility in Newcastle.



Figure 2 Parabolic trough solar collector at the Shams Solar Power Station in Abu Dhabi.



Compare and contrast



Concentrated Solar Thermal Technology

Ambient Solar Thermal Heating/Radiation

Differences

-

-

Similarities

-



Investigation focus question



Produce - What questions do you have about the two stimulus images?

Write as many questions about the stimulus images as you can. Do not worry about spelling or perfection, just write the first questions that comes to mind. Change any statements to questions.

-

Improve, refine, prioritise - Rewrite one closed question to an open question and one open question to a closed question.

Open: encourages a unique detailed answer. Closed: short, specific answers.

-

Focus question breakdown - What questions are within your focus question?

Break your focus question down into smaller questions that you will need to explore, and any skills you will need to learn.

•	•	•
•	Write focus question here. •	•
•	•	•



Investigation focus question



You may have heard the saying, *'Only mad dogs and Englishmen go out in the midday sun.'*

It's a humorous reminder that standing in the blazing sun isn't always a good idea. However, what if we could capture that intense sunlight and use it productively?

Scientists around the world are doing just that by collecting and concentrating sunlight to create heat. This heat energy can be transferred to a fluid, such as oil or molten salt, which is then used to heat water, produce steam, and power turbines that generate electricity.

Countries like Spain and the United States have already built large Concentrated Solar Thermal (CST) power plants, and Australia is now joining them. With our first commercial CST plant expected to begin producing electricity in late 2025, researchers at CSIRO are helping turn Australia's abundant sunlight into a reliable, renewable source of power, even after the sun goes down.

Aim:

In this activity, you will build a solar trough and use the trough to convert solar radiation to solar thermal energy.

Focus question:

Plan and conduct a reproducible investigation:

A scientific experiment must have the ability to get consistent results. That means, the experiment must get the same results if repeated under the same conditions. Therefore, only one variable is changed, at least one is measured, and as much as possible, all other variables are kept the same.

How will you ensure this experiment has a high reproducibility?

In this investigation, I am going to:

Change _____ and measure
_____, while keeping
_____ the same.

Prediction:

What do you think will happen to the objects? Why do you think this will happen?

Capturing and using solar radiation from the sun will:

Investigation: Build a solar trough



Equipment

- 1x Cardboard box
- Aluminium foil
- Card (A3 sheets)
- Elastic bands
- Sticky tape
- Objects to be heated (e.g. stone, chalk,
- wooden item, metallic item etc.)
- Calculator
- Scissors
- 2 x Paper cups with lids or equivalent insulated containers (calorimeter)
- 2 x Thermometers
- String or wire
- 2 x 30cm rulers
- Tongs

Procedure

Part 1 – Building a solar trough

1. Find a cardboard box (Shoebox, tissue box or similar size – relative to the size the heated object See figure 1.).
2. Cut the A3 card to the same length of the box. Glue or tape aluminium foil to one side of the card, completely covering the card.
3. Cover the two inside shorter sides with aluminium foil and glue or tape in place. **NOTE** – the smoother the foil the better the result.
4. Place your card in the box to form a trough. **NOTE** – a wider rather than deep trough will allow more room to attach objects at the focal point of your trough.
5. Secure the card in place with sticky tape.
6. Measure and record the diameter of the parabola and the depth of the parabola.
7. Determine the focal point of your trough using: $f = x^2/4a$ (Where f is the focal point, x is the radius, a is the depth).
8. Pierce the two short sides of the box exactly at the focal point you calculated.

- Thread string or wire through the hole you made in the side of the box. Secure the string/wire in place. Thread the other end through the hole at the other end of the box, so the string/wire runs along the length of the trough at the focal point.

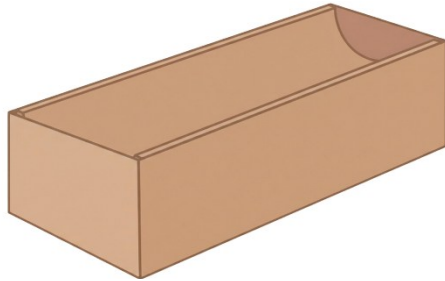


Figure 4 Cardboard box

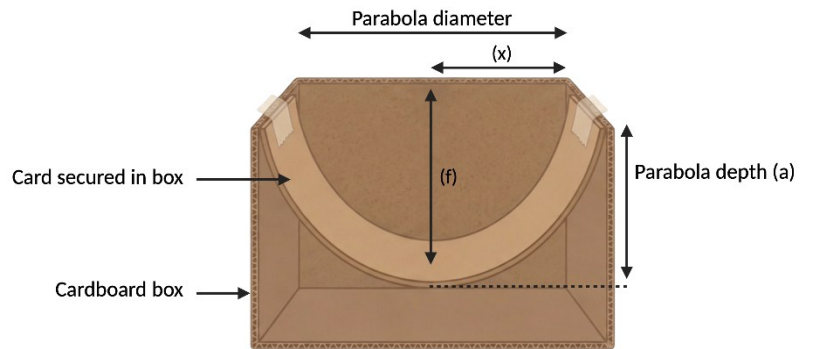


Figure 3 Cross section of cardboard box

Part 2 – Heating the objects

Select the two similar objects you are going to test.

- Using elastic bands or similar attach one of the objects to the string/wire in your solar trough.
- Find a suitable location to place your solar trough – outside or near a window.
- Position the solar trough facing the sun and angle it to get the maximum amount of sunlight and secure it in place. Leave your second object on the floor next to your solar trough.
- Leave the solar trough and the second object in place for a minimum of 15 minutes (The longer in the sun the better).

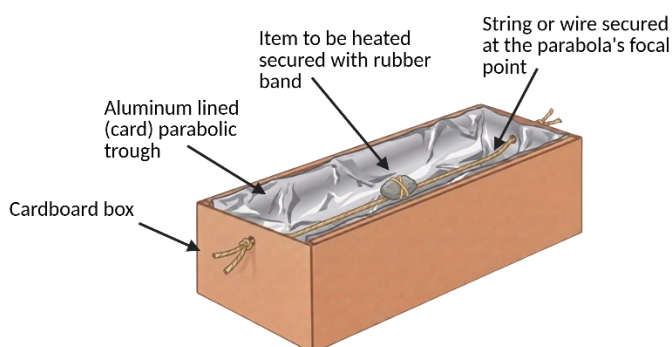


Figure 6 Solar trough

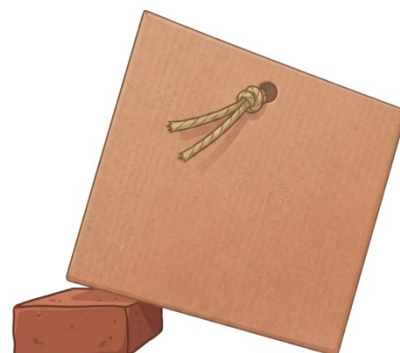


Figure 5 Solar trough tilted toward the sun

Part 3 – Recording the thermal energy

14. While your object is warming, set up your calorimeter as shown in *figure 5* (minus the object being tested). If your calorimeter does not have a lid a flat piece of cardboard will do.
15. Pierce a hole in the lid/cardboard large enough for the thermometer to fit through, but tight enough to prevent the thermometer from sitting on the base of the calorimeter.
16. Record the temperature in the calorimeter (Record your findings on Pages 21-22) – this is your initial temperature. Using tongs, carefully remove your object from the solar trough and place it in the calorimeter.
17. Place the lid on the calorimeter and record the temperature every 30 seconds for 5 minutes.

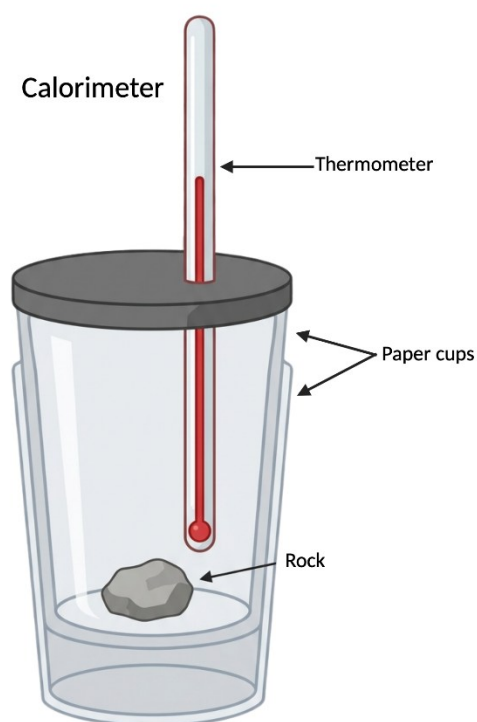


Figure 7 Calorimeter setup



Investigation process diary



Here is where you are going to keep track of your progress towards your goals. You will reflect on what you have learned, your progress, and what you need to do in future lessons to stay on track.

Lesson date	Reflection
	<p data-bbox="427 707 539 741">Today I:</p> <p data-bbox="427 1055 667 1088">Next lesson I will:</p>
	<p data-bbox="427 1373 539 1406">Today I:</p> <p data-bbox="427 1720 667 1753">Next lesson I will:</p>

Lesson date	Reflection
	<p>Today I:</p>
	<p>Next lesson I will:</p>
	<p>Today I:</p>
	<p>Next lesson I will:</p>

**Teamwork
Check-in**
(rate your
group's skills out
of 5 stars)

We are listening carefully to each other's ideas: ☆☆☆☆☆

We are sharing the work: ☆☆☆☆☆

We are staying on task: ☆☆☆☆☆

Record your results



Results – Solar trough

Record the temperature (°C) of each object at the indicated time intervals below:

Temperature (°C) per object	Time (minutes)										
	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Object 1											
Object 2											
Object 3											

Results – Ambient solar

Record the temperature (°C) of each object at the indicated time intervals below:

Temperature (°C) per object	Time (minutes)										
	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Object 1											
Object 2											
Object 3											

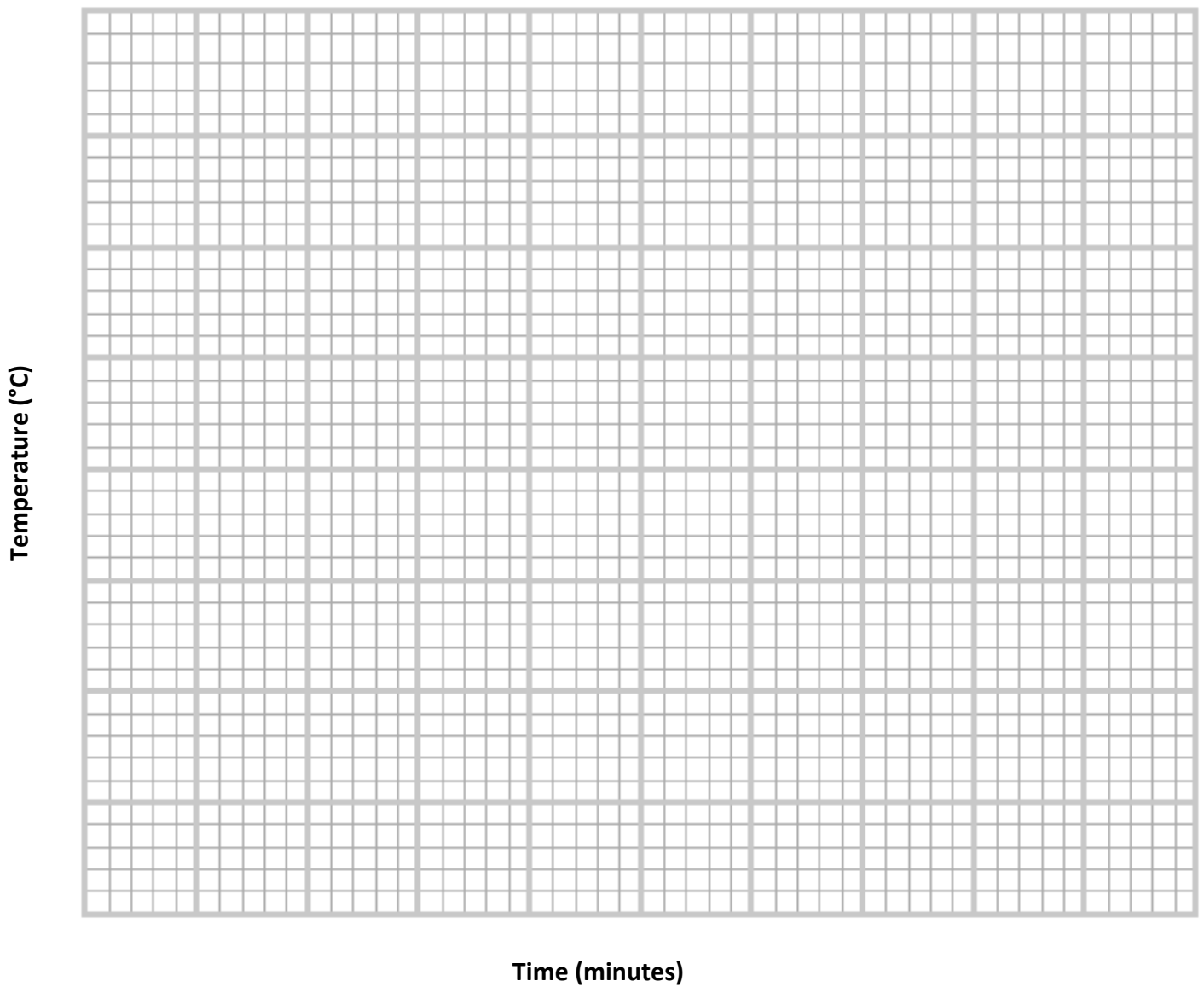


Create a results grid



Plot your results on the grid. Remember to fully label your graph.

Temperature of heated objects over 5 minutes





Analysis and conclusion



Analysis

Observations – What did you observe for the objects heated in the solar trough? (Describe what you saw).

What did you observe for the objects heated using ambient solar radiation?

Do your results support your prediction?

Discussion

What do your results tell you and what evidence do you have? Based on your results, are you able to answer your focus question?

Evaluation

Are your results reliable? Why, or why not?

Describe any problems you encountered during this investigation and outline what changes you would make to overcome them next time.

If you were going to do this investigation again, what changes would you make?

Conclusion

What conclusion can you make about the differences in the thermal energy of the objects in the different heating methods? What evidence do you have to support your conclusion?



Thermal energy storage diagram



Draw and label a diagram of how you could upgrade an existing energy system in a building to use stored thermal energy.

A large, empty rectangular box with a thin black border, intended for the student to draw and label their diagram of a thermal energy storage system upgrade.



Presentation plan



How will your team present your project? What is the best way to share everything you have learned?

Use this table to plan your presentation, including who is responsible for each task/section.

Task	Team member/s responsible	Due date
•	•	•
•	•	•
•	•	•
•	•	•
•	•	•



Investigation reflection



What parts of the investigation were successful? Why were they successful?

-

How can improvements to thermal energy storage help to reduce greenhouse gasses in Earth's atmosphere?

-

Describe two challenges you had to overcome during this investigation. What steps did you have to take to overcome them?

-

What would you do differently if you had to complete this investigation again? What could have made this investigation even better?

-

Where will you use what you have learned in your life outside of school? How can you use your knowledge from this investigation to make a difference (big or small)?

-



Take it further: extension activity



- Calculate specific heat of the object and compare values obtained from the concentrated solar energy and ambient solar energy. AND/OR calculate and compare the specific heat of two different objects.
- Research a current Australian CST or thermal energy project:
 - MGA Thermal (Newcastle, NSW)
 - Vast Solar (Port Augusta, SA)
 - CSIRO RESS program.
- Identify key challenges in scaling energy storage technologies (e.g., cost, materials, location).

Additional investigation task

Concentrated Solar Thermal (CST) systems use an array of mirrors to concentrate sunlight onto a target to heat a thermal medium to very high temperatures. This heat can then be used directly for industrial process heat or be used to generate electricity. Several storage mediums exist including concrete, rocks, and graphite. The most common medium, molten salt, passes through a heat exchanger, transferring the heat to water to produce steam. This steam then rises and passes a turbine to generate electricity.

Use the internet to find two examples of concentrated solar thermal installations:

Example 1:	Example 2:
<ul style="list-style-type: none">•	<ul style="list-style-type: none">•

What might be some of the main considerations or potential challenges if you were planning a concentrated solar thermal installation?

How might you overcome some of the challenges you may have identified above?

Science investigation planner



Inspiration for investigations can come from anywhere; curiosity, observations, problems or things you've seen in the world around you! Use this planner to help design and carry out your own investigation.

- When planning your investigation, remember it should be:

Reproducible

- Only change one thing – independent variable.
- Measure at least one thing - dependent variable.
- Keep everything else the same – controlled variable.

- Keeping your investigation fair makes sure your results are caused by the things you change, not by something else.

Repeatable

- Write your method clearly and in order so another person can follow it exactly.
- Include all materials, measurements and steps.

- If another person repeated your procedure, they should get similar results.

Reliable

- Collect enough data to make sure your results are accurate.
- Repeat your experiment several times to check for consistency.

- Record all measurements carefully – if repeated attempts show similar results, your data is more reliable.

Valid

- Your procedure and data must match your investigation/focus question.
- Make sure what you are testing answers your question.

- If your experiment measures something unrelated, your results won't be valid.

Scientists always check their investigations for fairness, repeatability, and validity before they share their findings. Use the list (above) as you plan, test and evaluate your work.

Introduction

Name

Date

Group members

What are you going to investigate? Write the focus question for the investigation:

What do you think will happen? Make a prediction and explain why:



Let's explore!



It's time to find out some more information about the topic.

Research the topic online and record the most important parts below so you can communicate them back to your team once you're done.

Resource name	What I found out (facts, statistics, interesting information)
<ul style="list-style-type: none">	<ul style="list-style-type: none">
<ul style="list-style-type: none">	<ul style="list-style-type: none">
<ul style="list-style-type: none">	<ul style="list-style-type: none">

Note: a resource is something that can be used to help you. Here, we can use news articles, blogs, books and images as resources to find out more about heat.

Reflect

What new questions do you have about the topic? Where might you find the information, you need to answer these? Who could you ask?

Question/s	Where will I look for information?
<ul style="list-style-type: none">•	<ul style="list-style-type: none">•



Our team timeline



Now that you know more about the topic, it is time to make a plan for your team's project.

Week/Lesson	Task/Activity	Resources, materials or support needed
<ul style="list-style-type: none">•	<ul style="list-style-type: none">• Choose our team's focus.•	<ul style="list-style-type: none">•
<ul style="list-style-type: none">•	<ul style="list-style-type: none">•	<ul style="list-style-type: none">•
<ul style="list-style-type: none">•	<ul style="list-style-type: none">•	<ul style="list-style-type: none">•
<ul style="list-style-type: none">•	<ul style="list-style-type: none">•	<ul style="list-style-type: none">•
<ul style="list-style-type: none">•	<ul style="list-style-type: none">•	<ul style="list-style-type: none">•
<ul style="list-style-type: none">•	<ul style="list-style-type: none">• Finalise our presentation.• Prepare for presentation.•	<ul style="list-style-type: none">•



Investigation planning



What variables are relevant to your investigation? List as many as you can think of:

•	•
•	•
•	•
•	•
•	•
•	•

Which variable are you going to:

Change? This is the <i>independent</i> variable.	Measure? This is the <i>dependent</i> variable.	Keep the same? This is the <i>controlled</i> variable.
•	•	•

List the equipment you will use and draw a diagram of how it will be set up:

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Risk assessment



When designing an investigation, it is important to think about safety. A risk assessment will help you to identify the hazards (something that could potentially cause harm) and record the actions/controls that you are going to put in place to reduce the risk.

Activity <i>e.g. Cutting templates with scissors.</i>	Hazard identification (type/case) <i>e.g. Cut to skin.</i>	Level of risk (high, medium or low) <i>e.g. Medium.</i>	Elimination or control measures <i>e.g. When using scissors, cut in direction away from body.</i>
•	•	•	•
•	•	•	•
•	•	•	•
•	•	•	•
•	•	•	•
•	•	•	•
•	•	•	•
•	•	•	•

Results



Record your data in a table in your science journal (workbook). Don't forget to include headings for each of your table columns.

You can also record your results using words and sentences, by drawing diagrams, taking photos or videos, or using digital devices.

Optional: Communicate your results using graph paper. Draw your axes, label the features of the graph and include a title.

Explaining your results

What happened to the dependent variable when you changed the independent variable?

Why do you think this happened?

Did the results support your prediction? If not, how were they different?

What challenges did you encounter in completing the investigation?

How could you improve the fairness, reliability or validity of this investigation?



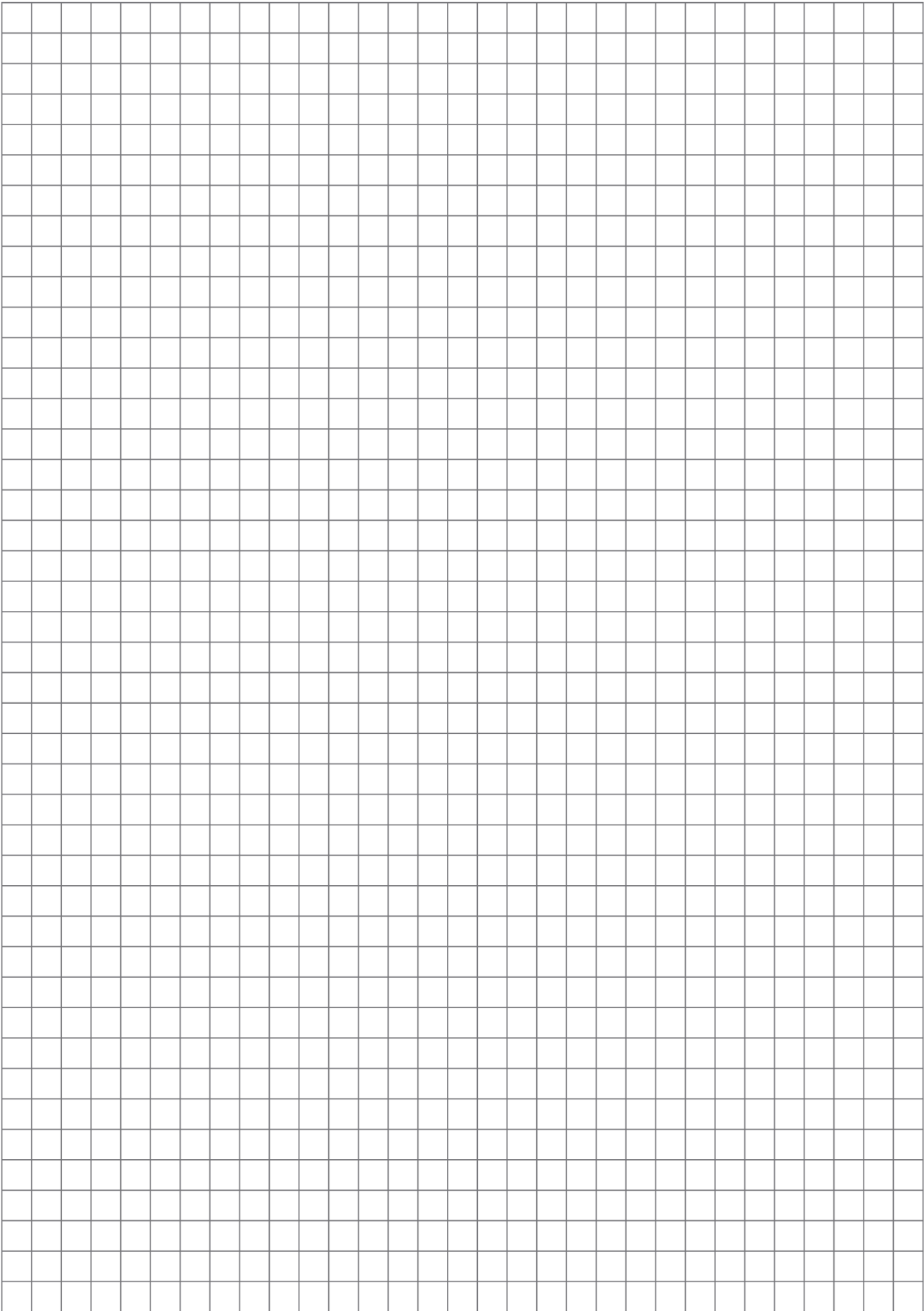
Research journal

Use this space to write down any resources you find and use in your investigation/s:

Resource name	What I found out
•	•
•	•
•	•
•	•
•	•
•	•

•	•
•	•
•	•
•	•
•	•
•	•
•	•
•	•
•	•

Graph paper (5mm)



Graph paper (10mm)

