Investigating Scientifically

Support for Stage 3 Teachers

A teaching resource developed by the
Science Unit, Curriculum K-12 Directorate

NEW SOUTH WALES
DEPARTMENT
OF EDUCATION
AND TRAINING

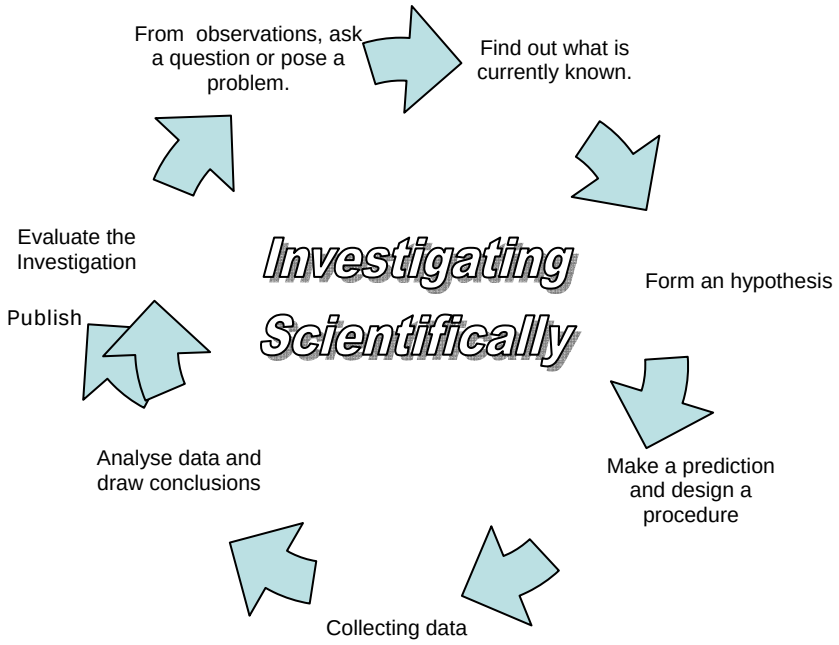
Acknowledgements

Harris Vassila Senior Curriculum Advisor, Science, K–6
Officers of the Science Unit, Curriculum K-12 Directorate

The investigating scientifically process involves students using the processes of observing, questioning, planning, predicting, testing, collecting , recording and analysing data to draw conclusions in order to develop a better understanding of the world around them. This process relies heavily, but not exclusively, on first hand information.

First hand information is information that students gather through their own observations and experimentation. The investigating scientifically process differs from the information research skills of defining, locating, selecting, organising, presenting and assessing. These research skills primarily involve students using second hand sources of information, such as books, journal articles, CD ROMs and internet browsing and searching.

The investigating scientifically processes is shown below
As students work through the investigating scientifically process, they develop an hypothesis, predict outcomes, and design a procedure to test their hypothesis. The data collected during the investigation is analysed so that conclusions can be drawn. These elements distinguish a scientific investigation from all other forms of investigating.



When teaching the investigating scientifically process, teachers may use a linear strategy that is Step 1 – What do we want to investigate? Step 2 –What do we already know about the concept we want to investigate, Step 3 -What is the hypothesis we want to test? etc
A linear model of teaching the process of investigating scientifically is useful. It is also important to understand that as students develop their understandings of the process, they move backwards and forwards through the steps of the cycles as they seek to clarify what it is they are trying to find out and as more information is gained.

The NSW Board of Studies *Science and Technology K-6 Syllabus* refers to the investigative learning process as a series of skills that include; exploring and discovering, proposing explanations, predicting outcomes, testing and modifying understandings.

A practical example of how the investigating scientifically process may look in a Stage 2 or 3 classroom is explained below. The lesson sequence below addresses aspects of the outcomes from the physical phenomena content strand. In particular, **PP S3.4** Identifies and applies processes involved in manipulating, using and changing the form of energy.

Conceptually, during Stage 3, students learn to recognise that a scientific investigation is a series of steps designed to examine a phenomenon. Students should learn to become more self-reliant in planning and carrying out investigations. Students learn to appreciate that there are different types of investigations and that evidence necessary to their support conclusions. Furthermore, students appreciate the need for specialist equipment and techniques to assist the processes of observing, recording, modelling and communicating.

Students should bring a greater understanding of scientific knowledge to their investigations and they are more able to appreciate and reflect on developments in science and technology.

The NSW Board of Studies Science and Technology K-6 Syllabus, Stage 3 investigating outcome, states that students should be able to:

INV S3.7: Conduct their own investigations and make judgments based on the results of observing, questioning, planning, predicting, testing, collecting, recording and analysing data, and drawing conclusions.

The Big Ideas
The Big Ideas have been developed to assist teacher's understanding of outcomes and to appropriately stage scientific content. The big ideas for the stage 3 investigating outcome **INV S3.7,** are listed below.
Big Ideas
- Constructs appropriate self-questions to guide investigations.
- Decides the type of data needed and works cooperatively to collect such data.
- Plans repeat trials of tests or experimental procedures.
- Identifies factors that are to be kept the same when carrying out tests or conducting investigations, and recognises the term **controlled experiment**.
- Ensures that equipment is working and can be used effectively and safely.
- Records data in an appropriate form and evaluates collected data to ensure that it satisfies the purpose of an investigation.
- Transforms data to show important relationships, trends, patterns or associations.
- Uses the ideas of fair testing to evaluate whether predictions or explanations are reliable and valid.

- Communicates what has been learned by choosing from a variety of media, tools and forms, taking into account audience and purpose.

When planning scientific activities, teachers need to select from at least one of the content strands (Earth and its Surroundings, Living Things, Physical Phenomena) for students to apply the process of investigating scientifically.

The complete list of Big Ideas can be found at http://www.qtp.nsw.edu.au/qtp/files/QTP_Primary/stage3/stage3_02_INV.html

	Big Ideas	***Assessment***
Observing and exploring (ask questions, pose problems, find out what is currently known) Teacher poses a problem to the class about an observed behaviour *Eg, Luke's father often gets distracted when making his morning cup of hot chocolate. By the time he returns (usually 10 minutes) to drink his hot chocolate, he finds that it is cold and undrinkable. The hot chocolate is poured down the sink and Luke's father makes a new one.* *Luke would like to help his father by investigating ways of keeping the hot chocolate warm and avoid wasting the hot chocolate.*		
Teacher introduces/ revises the notion of a scientific investigation as a systematic inquiry process that requires students to plan a course of action, carry out the activity and collect the necessary data, organise and interpret the data, and reach conclusion which is communicated in some form. (Garnett and Hackling (1995)) ***(Teacher can use student worksheet 1 as an activity to revise the steps in investigating scientifically process)***		
Observing and exploring (ask questions, pose problems, find out what is currently known) 1. Teacher leads the class in a brainstorming session to help the students define the question that they will investigate, eg *eg, How can we keep the hot chocolate warm?* *What do we know about keeping things warm?* *What additional information do we need to find?* A mind map ***(Student worksheet 2)*** could be used in the brainstorming session to help students clarify what they know and what they need to find out. ***Resource sheet 2 and Resource sheet 2a are examples of completed***		

mind maps. *eg ,Will insulation keep our coffee from going cold?* *Does the type of cup affect heat loss?* *Does the starting temperature of the hot chocolate affect the heat loss?* *Does the size of the cup affect heat loss?* *Does the material the cup is made from affect heat loss?* Students may be guided to *research* from secondary sources such as books, CD ROMs, internet etc. to find out about concepts such as *heat transfer, temperature, sources of heat…* Once the research is completed students should share their understandings by contributing in a class discussion. Teachers may guide the students during the class discussion to ensure the relevant and correct scientific concepts and language are used. *Eg, Energy is transferred from a body of high temperature to one of a lower temperature.* *Energy can be transferred through all materials even through empty space.* *Convection is a process by which energy is transferred in liquids or gases.* *Conduction is the process through which energy is transferred through solids.* 2. As a class, brainstorm possible investigations that can be constructed to solve the problem or answer the questions. (This can be done by either creating a new mind map or adding the new knowledge to the initial mind map. (***Student worksheet 2)***)		
Hypothesising and Predicting (define a problem that can be investigated scientifically) Students with teacher assistance develop an hypothesis related to their chosen	Stage 2 • Poses “decide which”, “find a way to” or “find the effect of” questions.	***Assessment opportunity*** Can the student:

investigation. Students should be guided to identify the relationship between the independent and dependent variables. (***Resource sheet 3 provides information on developing a useful hypothesis)*** **Example hypotheses** *Foam cups will keep hot chocolate warmer than paper cups.* *Smaller mugs will keep hot chocolate warmer than larger mugs.* *Insulated mugs will keep hot chocolate warmer than non insulated mugs.* *Tall mugs will keep hot chocolate warmer than short mugs.* ***(Resource sheet 4 provides an example of an activity that may help students identify the variables in an investigation)***	Stage 3 • Constructs appropriate self-questions to guide investigations.	• pose simple scientific questions for testing and makes predictions
Devising and Testing (describe a procedure for collecting data, identify appropriate equipment to carry out the procedure) Discuss with students how they could make their investigation fair. Students should identify the variables that could affect the results of the investigation, and therefore, need be kept constant. Students should be able to identify the independent variable and the dependent variable. *e.g., The variables would include such items a the size of mug, shape of mug, composition of mug, initial temperature, water impurities, quantity of milk, ambient temperature, and instruments used to measure temperature*. Discuss with students how they could ensure their investigation is reliable; e.g., Is what I have chosen to measure and the way that I measure it able to be repeated/replicated with consistent results? Can the students repeat their investigation? Would they need to replicate the investigation?	Stage 2 • Identifies, with guidance, the types of measurements and data to be collected and decides how to do this and with whom. • Uses equipment accurately, reliably and safely. Stage 3 • Decides the type of data needed and works cooperatively to collect such data. • Plans repeat trials of tests or experimental procedures. • Identifies factors that	***Assessment opportunity*** Can the student: Recognise what a fair test is and the need to have a fair test • Identify variables that need to be changed, measured and controlled.

How many times should students repeat or replicate their investigation? Provide the students with a procedure proforma. ***(Student worksheet 3)*** Explain or discuss with students the experimental procedure and the process for collecting data and the equipment needed to conduct the investigation. Alert students to possible risks involved in conducting their investigation and ensure appropriate risk management procedures are followed. *Depending on the student's level of development, stage 3 students should be encouraged to develop the procedure for their investigation independently.* ***(Example procedures are provided on resource sheet 5)***	are to be kept the same when carrying out tests or conducting investigations, and recognises the term controlled experiment. • Ensures that equipment is working and can be used effectively and safely.	
Collecting and recording data (use the procedure and equipment to collect and record data) Students conduct their investigation in pairs or small groups with guidance. Teachers should demonstrate/model to students the importance of making accurate and precise measurements. Note: *Depending on the level of development of the students, the teacher may provide a proforma for the students or allow the students to independently develop their own method of recording their observations.* ***(Resource sheet 5a)***	Stage 2 • Records data in an appropriate form and works out trends or patterns in the collected data.	***Assessment opportunity*** Can the student: • Makes simple standard measurements • Collect and record data as tables, diagrams or descriptions
Analysing and Drawing Conclusions (reach a conclusion which is communicated to others) Once all the data is collected, a careful and systematic analysis should be conducted to identify if the evidence gathered supports the hypothesis. Students should analyse the collected data as well as evaluating the procedure and instruments used in their investigation. Constructing graphs is one method of analysing the student's data. Spread sheet applications assist in producing effective graphs once the data has been	Stage 2 • Comments on the limitations of the investigations in relation to equipment, size of sample, repeatability. • Suggests improvements to procedures. Stage 3 • Records data in an	***Assessment opportunity*** Can the student: Displays data as tables or constructs graphs; when given the variable for each axis. Identify and summarise patterns in the data in the

entered. Teacher should discuss with students the various types of graphs and assist students to choose an appropriate graph to best represent their data ie column graphs for discontinuous data, line graphs for continuous data. Teachers may lead the class in a discussion to describe trends and patterns in the student data. Reference should be made to the hypothesis; Do the trends support the hypothesis? What scientific explanation is there for the results? Evaluate the investigation by identifying possible sources of error and suggest improvements to the investigation. Students/teachers can suggest further investigations arising from the results. Teacher and students jointly, or students independently, write a conclusion. The information gained from this investigation may lead to a design and make activity i.e. designing a more efficient mug.	appropriate form and evaluates collected data to ensure that it satisfies the purpose of an investigation. • Transforms data to show important relationships, trends, patterns or associations. • Uses the ideas of fair testing to evaluate whether predictions or explanations are reliable and valid.	form of a rule. Recognise the need for improvements in the method or equipment used Describe the relationship between events that have been experienced or observed generalise and apply the rule by predicting future events
Publishing and Presentation Students should be encouraged to present their investigation to an audience. ***(Resource sheet 6)*** Presenting their findings provides students with an opportunity to reinforce and showcase their learning. It can also provides the teachers with a valuable assessment opportunity. Presentations may be made through the construction of a: • scientific report • scientific poster • electronic presentation – web page, slide show etc Ensure that students are guided through the process of acknowledging sources of information, such as books, web sites and people that contributed to their investigations.	Stage 2 • Reports to others, using simple factual texts that have been chosen in consultation with the teacher, e.g. information reports, procedures and explanations. Stage 3 • Communicates what has been learned by choosing from a variety of media, tools and forms, taking into account audience and purpose.	

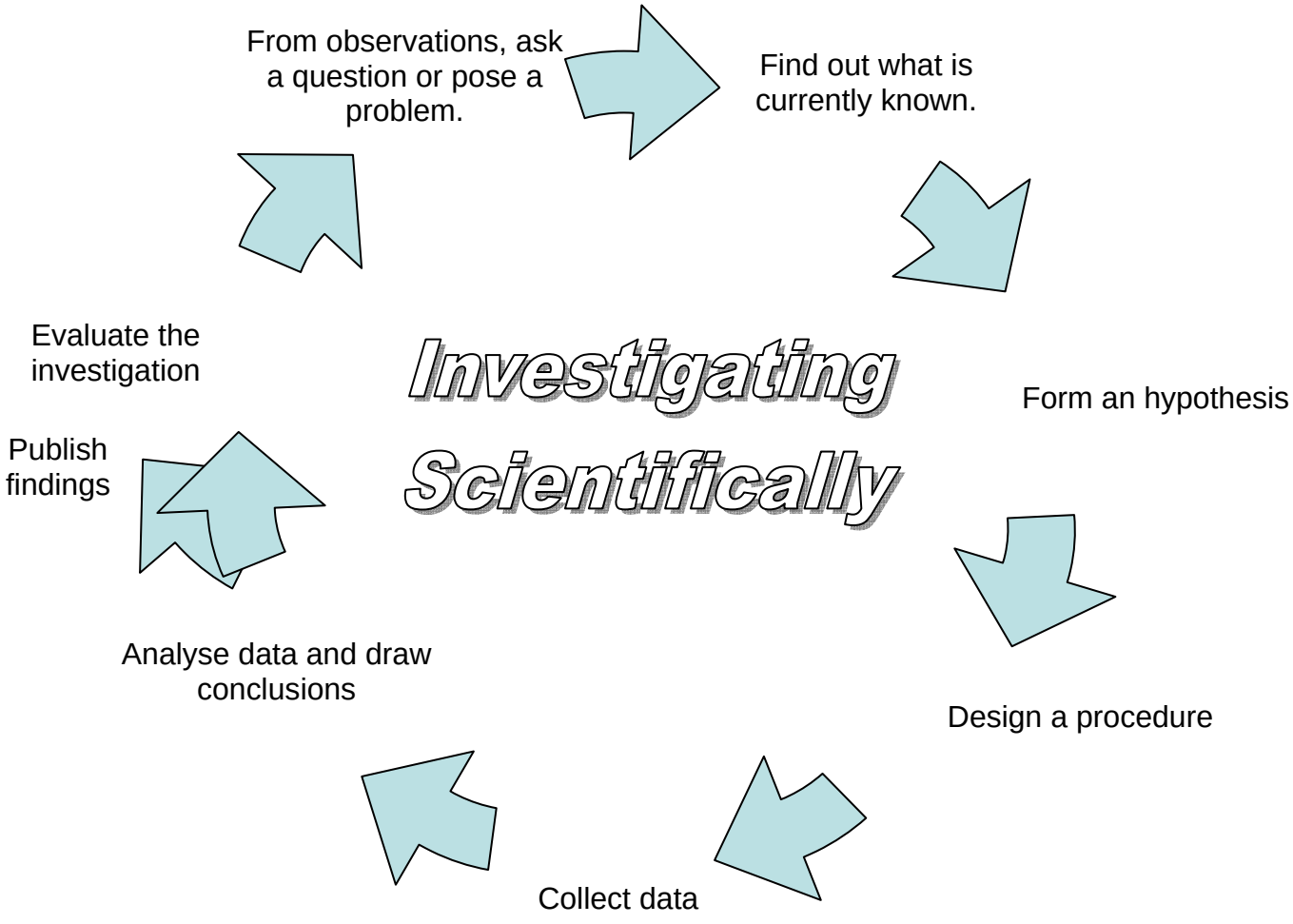
Resource sheet 1 – Investigating scientifically

For students to engage in the planning and carrying out of investigations and in communicating their findings, it is helpful to provide a model of the Investigating scientifically process. One such model is illustrated below and another model is provided on the next page. Each step in the process is considered to be significant for students to be successful.

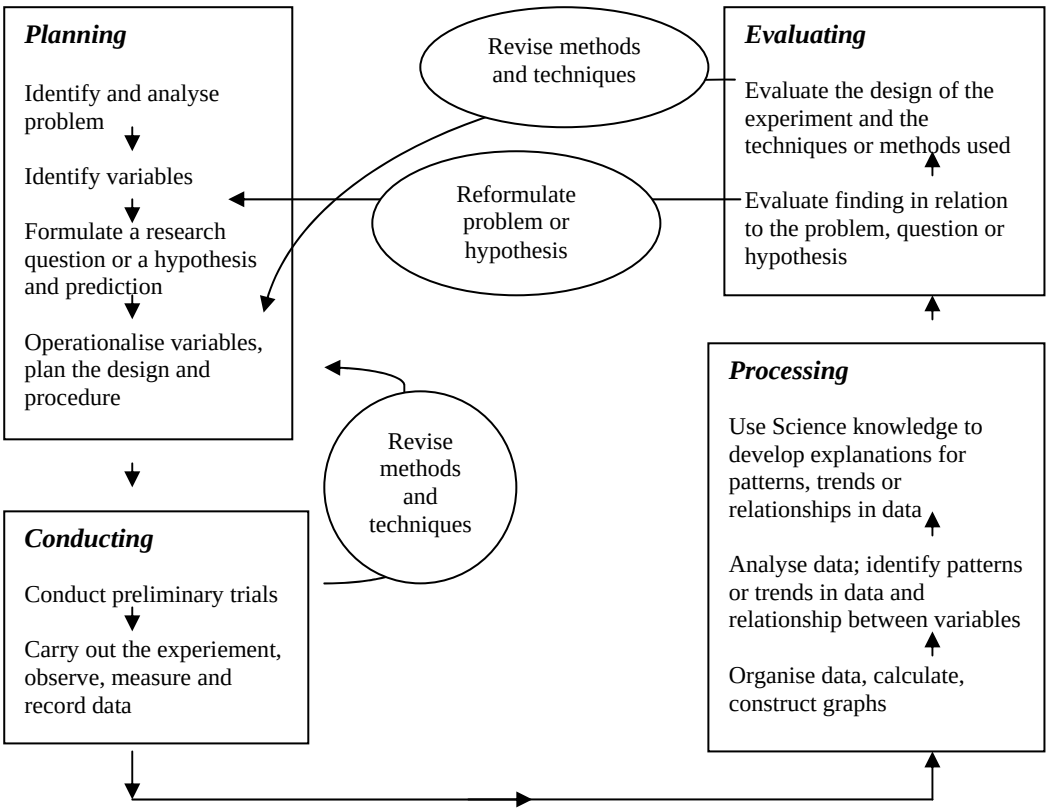
A definition

A scientific investigation:

- relates to a problem that can be formulated as an hypothesis for testing
- collects data for analysis that can be used to draw conclusions
- is communicated to allow scrutiny through verification.



Resource sheet 1a
Alternative model for the process of a scientific investigation



A model of science investigation process (Hackling & Fairbrother, 1996)

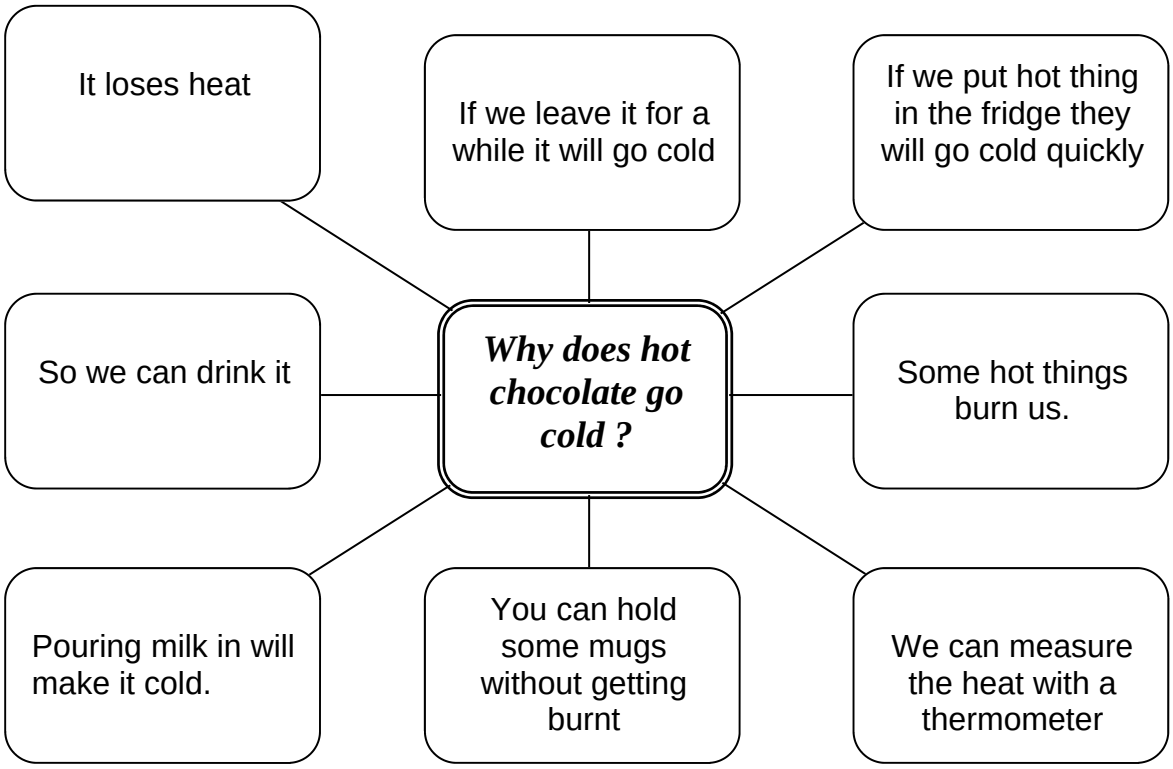
The degree of openness of an investigation depends on whether the teacher or the student is making the decisions. A *guided inquiry* might be appropriate in a Year 6 class, where the teacher models the activities, provides a problem, guides students through the procedure and the analysis of the result but encourages students to come to their own conclusions. An *open inquiry,* where a student makes decisions on all the aspects might be appropriate in a Year 10 class where the students have been through a modelled guided inquiry and practiced with an open guided inquiry and are now ready to plan and conduct their investigation independently.

Levels of openness of inquiry in laboratory activities

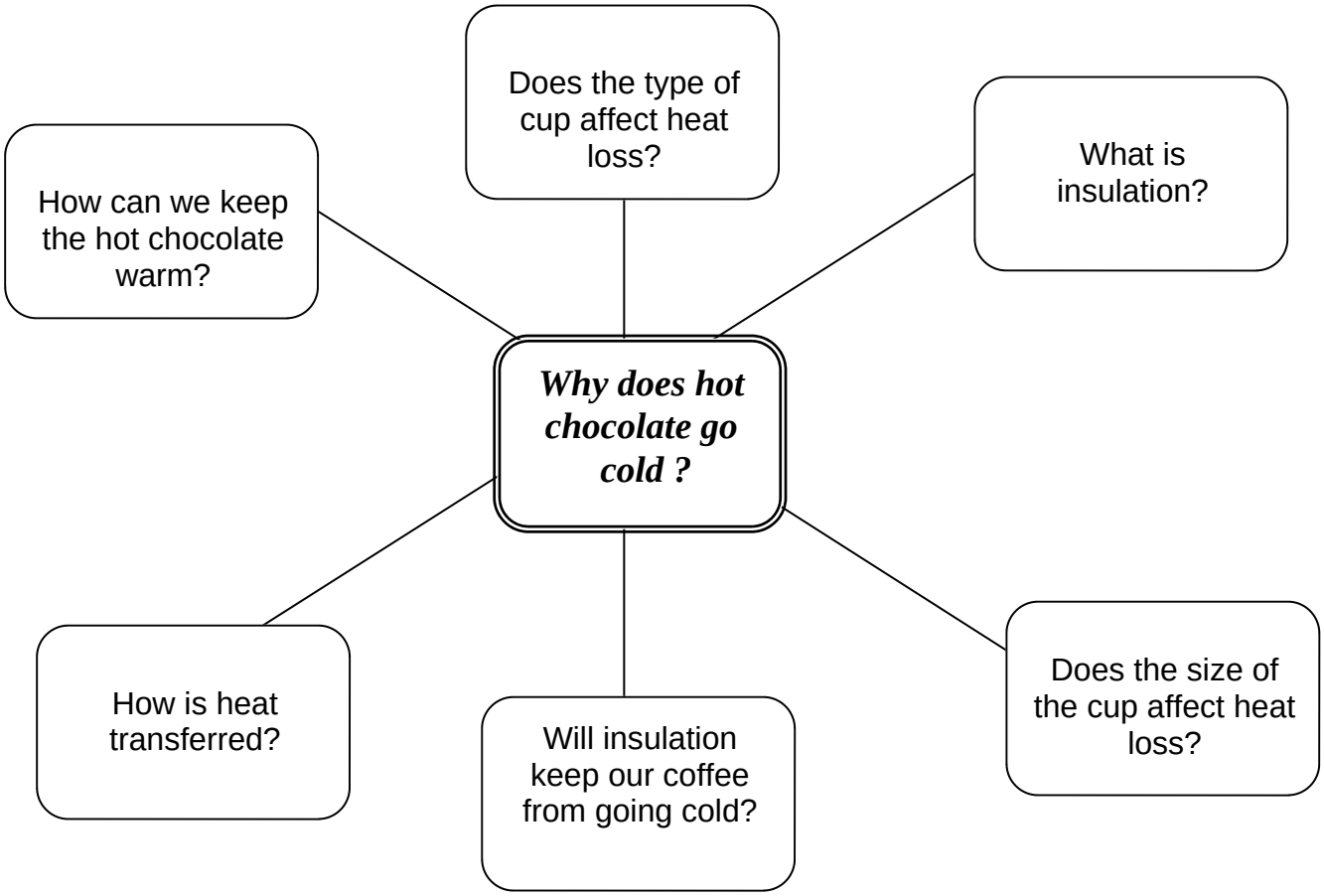
Level	***Problem***	***Equipment***	***Procedure***	***Answer***	***Common Name***
0	Given	Given	Given	Given	Verification
1	Given	Given	Given	Open	Guided inquiry
2a	Given	Given	Open	Open	Open guided inquiry
2b	Given	Open	Open	Open	Open guided inquiry
3	Open	Open	Open	Open	Open inquiry

(after Hegarty-Hazel, 1986)

Resource sheet 2 - What do we know?



Resource sheet 2a - What do we need to find out?



Resource sheet 3 – Hypothesising and predicting

One of the crucial steps in planning and conducting a scientific investigation is the determination of the hypothesis. Students typically need considerable scaffolding to work from their original question toward the formulation of an hypothesis. Many questions that students present are unsuitable for investigating scientifically. The step of gathering information about what is currently known with regard to their question often produces a more appropriate area for investigation. This still needs to be focused toward the identification of the variables involved, and from there, the formulation of an hypothesis.

What is an hypothesis?

An hypothesis is a statement that describes a relationship between two or more variables that can be tested. It can be worded as a statement by using the following scaffold:

When the **independent variable** is changed,

what happens to the **dependent variable** ?

Example

If the independent variable is (increased, decreased, changed) then the dependent variable will (increase, decrease, change.)

If the **amount of sunlight** is increased then the **height of wheat plants** will increase.

Hypothesis: The amount of sunlight increases the height of wheat plants.

An hypothesis is not the same as a guess or an inference as it is made after considering all the information available. It is not the same as a prediction as it tries to explain more than one observation or one situation.

A prediction may be made after an hypothesis has been formulated and it is related to the particular situation being tested and may therefore be proven, However, the hypothesis which is related to more general situations or observations can not be proven through one testing procedure.

For example, an hypothesis might be *That smaller balls bounce higher than larger balls.* Data obtained by testing a number of different sized balls over a number of trials may support this hypothesis or the data may not support it. However, the data from one testing procedure will not prove whether the hypothesis is correct or not. On the other hand, a prediction might be made that the tennis ball (one of the balls being tested) will bounce the highest of those balls that are being tested. This can, in fact, be proven to be correct or not.

Resource Sheet 4 – Can you identify the variables?

The **independent variable** is the variable that the investigator **CHANGES**.

The **dependent variable** is the variable that the investigator **MEASURES**.

The **controlled variables** are the other factors that may affect the outcome of the investigation and need to be **KEPT THE SAME**.

Hypothesis	**Changed Variable** (independent)	**Measured Variable** (dependent)	**Controlled Variable** (kept the same)
1. Foam cups will keep hot chocolate warmer than paper cups			
2. Smaller mugs will keep hot chocolate warmer than larger mugs			
3. Insulated mugs will keep hot chocolate warmer than non-insulated mugs			
4. Tall mugs will keep hot chocolate warmer than short mugs			

Suggested answers

1. type of cup (foam, paper) ; temperature over time
2. size of mug (volume, diameter) ; temperature over time
3. presence of insulation ; temperature over time
4. height of mug ; temperature over time

Resource sheet 5 – Sample procedures

Hypothesis 1

Foam cups will keep hot chocolate warmer than paper cups.

Sample Procedure 1

Select 2 cups of equal size made from styrofoam and paper and label them ‘A’ and ‘B’
Add equal amounts of hot water to each cup
Measure the initial temperature of the hot water in each cup and record the measurements
Measure and record the temperature of the water in each cup every minute for 10 minutes
Repeat the procedure 3 times

Hypothesis 2

Smaller mugs will keep hot chocolate warmer than larger mugs.

Sample Procedure 2

Select 2 mugs of differing sizes (one large and one small) and label them ‘A’ and ‘B’
Add equal amounts of hot water to each mug
Measure the initial temperature of both mugs and record the measurements
Measure and record the temperature of each mug every minute for 10 minutes
Repeat the procedure 3 times

Hypothesis 3

Insulated mugs will keep hot chocolate warmer than non insulated mugs.

Sample Procedure 3

Select 3 identical mugs and label them ‘A’, ‘B’ and ‘C’
Enclose mug ‘A’ with wool insulation; enclose mug ‘B’ with Styrofoam insulation and leave mug ‘C’ as the control with no insulation
Add equal amounts of hot water to each mug
Measure and record the initial temperature of all mugs
Measure and record the temperature of each mug every minute for 10 minutes
Repeat the procedure 3 times

Resource sheet 5a – Collecting and recording data

Hypothesis and sample procedure 1
Styrofoam Cup

Time		0 min (start)	1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	9 min	10 min
Temp (°C)	Test 1											
	Test 2											
	Test 3											
	Average											

Paper Cup

Time		0 min (start)	1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	9 min	10 min
Temp (°C)	Test 1											
	Test 2											
	Test 3											
	Average											

Hypothesis and sample procedure 2
Small Diameter Cup

Time		0 min (start)	1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	9 min	10 min
Temp (°C)	Test 1											
	Test 2											
	Test 3											
	Average											

Large Diameter Cup

Time		0 min (start)	1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	9 min	10 min
Temp (°C)	Test 1											
	Test 2											
	Test 3											
	Average											

Hypothesis and sample procedure 3
No Insulation

Time		0 min (start)	1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	9 min	10 min
Temp (°C)	Test 1											
	Test 2											
	Test 3											
	Average											

Wool/Styrofoam insulation

Time		0 min (start)	1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	9 min	10 min
Temp (°C)	Test 1											
	Test 2											
	Test 3											
	Average											

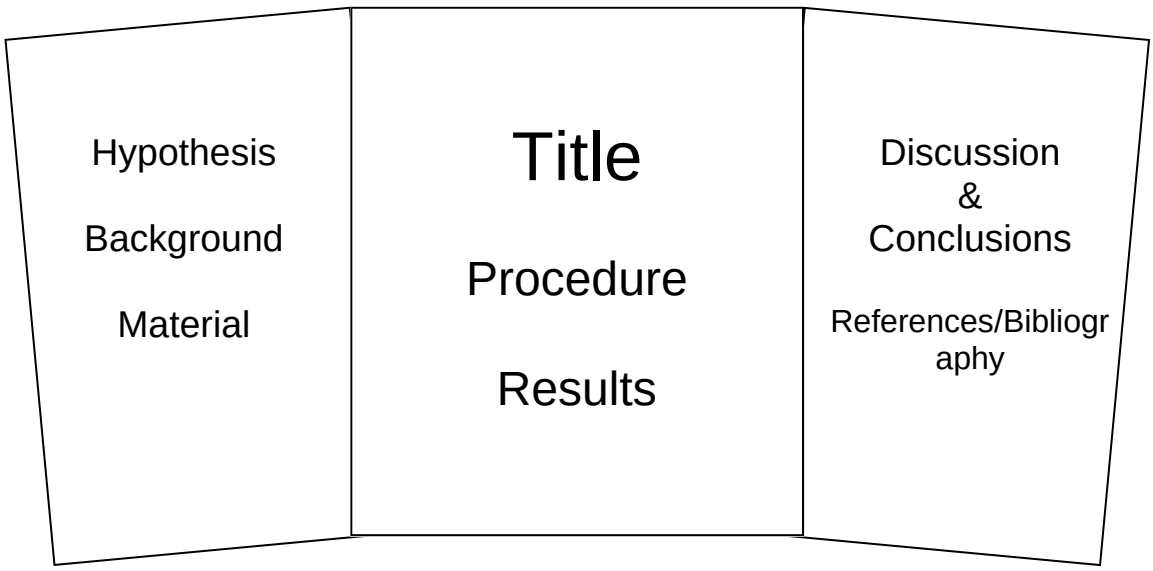
Resource Sheet 6 – Publishing and presentation

A presentation tells a story of an investigation. It can be published as either a poster, web page or it may take the form of an oral presentation using a slide show.

Student's presentations, regardless of there form, should aim to inform the audience about:

- What they investigated
- Why they were interested in the investigation
- How they did the investigation
- What they observed
- What the observation/results mean
- Why the results are important
- What they have learned
- What they may do next

Sample Poster Layout



The poster or report can be grouped under the following headings :

Hypothesis

The hypothesis is a statement that describes the relationship between the two variables that were being investigated.

Background

The background provides a brief summary of the science behind the investigation. Information for this section is usually derived from the initial research that was identified in the mind map ‘What do we need to find out?’ and includes information from secondary sources i.e. books, internet etc

Material

Lists the materials and equipment required to conduct the experiment. It should be suitably detailed so that people are able to replicate the investigation. Diagrams and picture may be useful to demonstrate the setup of equipment.

Procedure

The procedure describes the steps taken to collect the data. The procedure should explain what variable is being measured and how, which variable is being changed and by how much (ml, cm, degrees) and which identified variables are being kept constant. A flow chart is a useful way of writing a procedure.

Results

The results section shows the findings of the investigation. Diagrams, tables and graphs are often used accompanied with a few sentences describing the results.

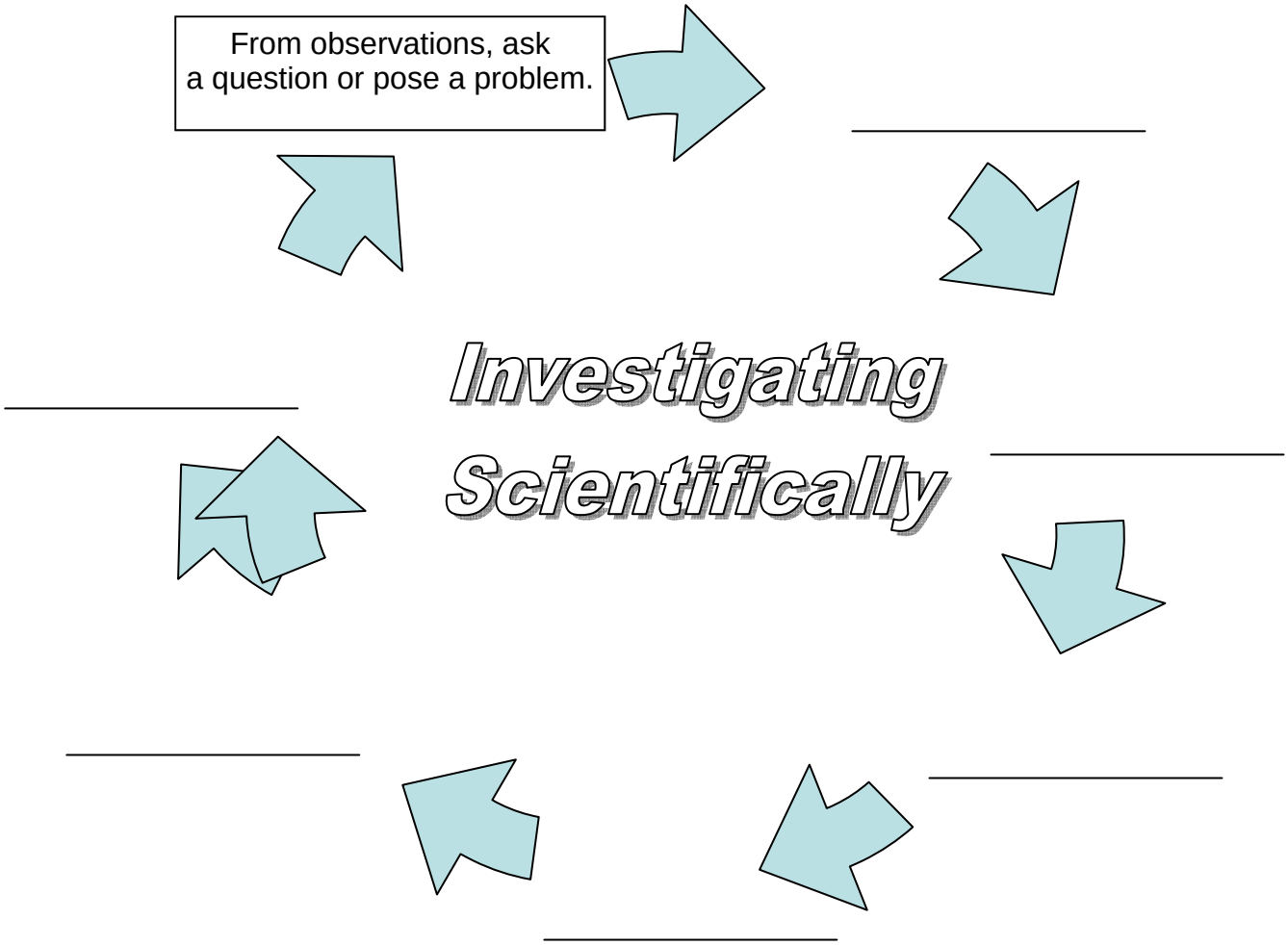
Discussion and Conclusion

This section relates to the hypothesis, students can explain what they have discovered and how this relates to the background information. Students should discuss how the investigation can be improved and what future investigation may involve. Students may suggest possible applications of their findings to the community.

Bibliography

It is important for students to recognise and acknowledge the people that have helped plan and conduct the investigation. This would include authors and their books, websites and people that they have spoken to.

Student worksheet 1 – Investigating scientifically



Instructions

1. Cut out the steps below in the investigative scientifically process

2. Arrange and paste each step into its correct position in the investigating scientifically cycle

Publish findings

Analyse data and draw conclusions

Collect data

Design a procedure

Find out what is currently known.

Evaluate the investigation

Form an hypothesis

Student worksheet 1a – Investigating scientifically

When in the process of investigating scientifically would you ask these questions?

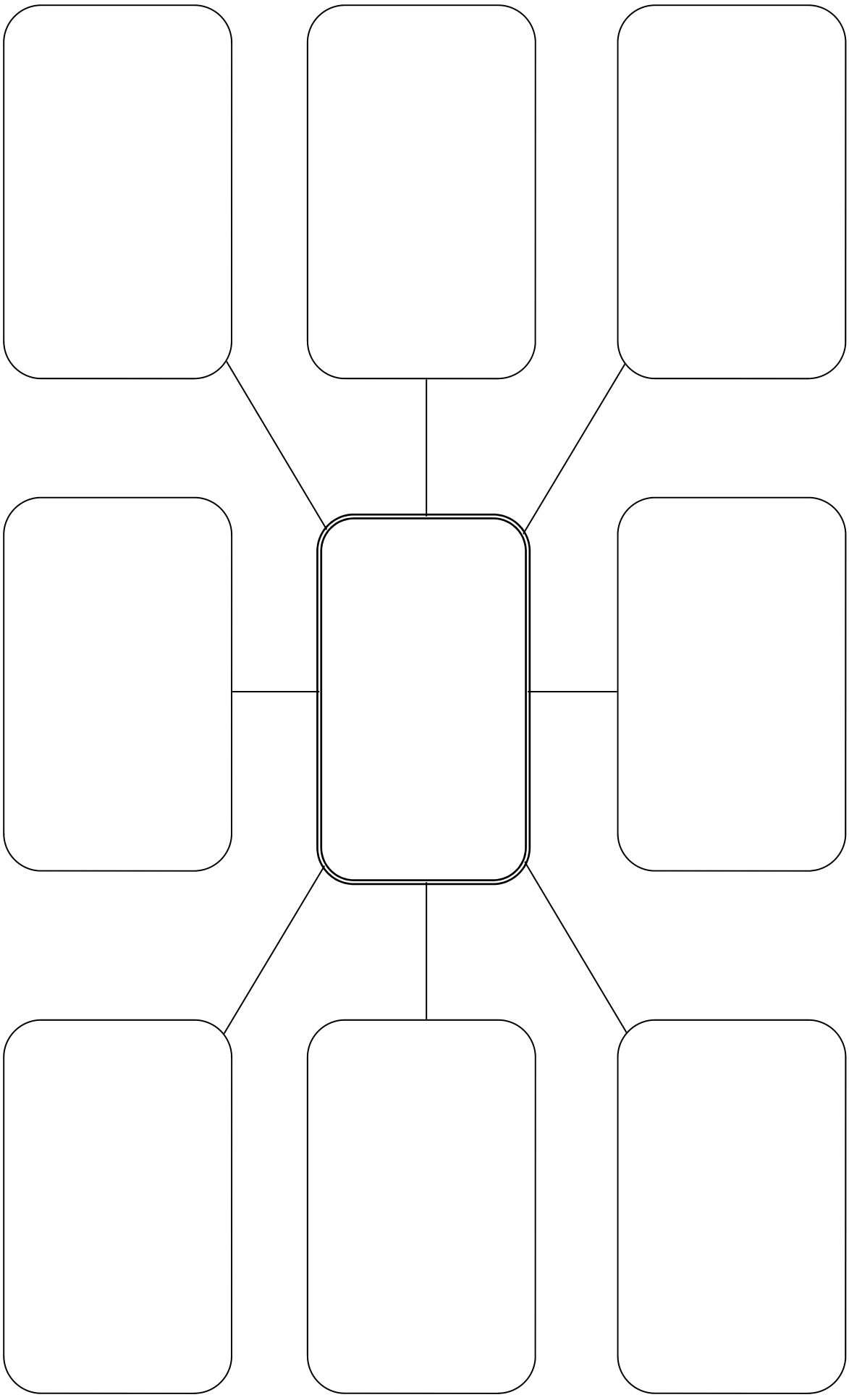
Have we written a statement that can be tested?
How will we measure?
What did we find out?
Was the data we collected reliable?
Why do we think this will happen?
How do we make this a fair test?
What did we hear?
How are we going to report our findings?
What do we think will happen?
What data will we collect?
What did we see?
How are we going to represent our data?
What do we already know?
What equipment do we need?
What are the variables that could affect the investigation?
Is their a pattern or trend in the data we collected?
What will we measure?
What will we change?
Is this what we expected to happen?
What would we change to make this a better investigation?
What will we investigate?

Instructions

Write each question in the most appropriate step of the investigating scientifically process

Observing and exploring	
Hypothesising and predicting	
Devising and testing	
Collecting and recording	
Analysing and drawing conclusions	

Student worksheet 2 - Mind map



Student worksheet 3 – Planning and organising

Observing and planning

What are you going to investigate?

What do you know about this topic?

Hypothesising and predicting

What do you think will happen?

Devising and testing

Which of the variables are you going to:

Change?

Measure?

Keep the same?

How will you make it a fair test?

What equipment will you need?

How will you measure the dependent variable?

What happened?

Analysing and drawing conclusions

What do the results tell you? Are there any patterns or trends in your results?

Can you explain the relationship, patterns or trends (try to use some science ideas)

Was the outcome different from your prediction? Explain.

What difficulties did you experience in doing this investigation?

How could you improve this investigation, e.g. fairness accuracy?