Thinking and working scientifically

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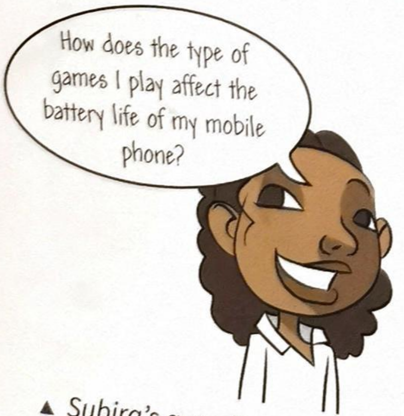
Objectives

- Recognise that there are many ways to find answers to questions in science
- Understand how to decide on a question to investigate
- Understand that there are some questions that science cannot answer

Part of making a prediction is to think about what might happen if your hypothesis is wrong. Your investigation should be able to show the difference between a correct and an incorrect hypothesis. Your conclusion will say whether the evidence supports, or does not support, your hypothesis.



▲ *Subira's question can be answered by doing a fair test.*

Asking questions

How do scientists answer questions?

We can ask lots of different questions about the world. Why does the batt last longer in some mobile phones than others? What might mobile phon be like in the future? Which mobile phone is best?

- There are questions that science can answer
- There are questions that science cannot answer.

What makes a question 'scientific'?

Scientists make **observations** and ask questions such as, 'How do fossil fuels form?' or 'Why are there are so many different animals on Earth?' These are scientific questions.

A scientific question is a question that you can answer by collecting and thinking about **data**. Data can be numbers from measurements, or words from observations.

Hypotheses and predictions

When they have a question, scientists may produce a **hypothesis.** A hypothesis is a scientific theory or proposed explanation made on the basis of evidence that can be further tested. A **prediction** is what you think will happen in the future. Scientists base their predictions on a hypothesis. Then they do an investigation or make further observations to collect data to see if their prediction is correct.

- A hypothesis is **testable** if you can:
- write a prediction based on the hypothesis
- collect data to see whether your prediction is correct.

Types of investigation

Scientists do **investigations** to collect data. There are lots of different types of investigation, for example:

- a fair test
- making a model
- a field study
- a survey or set of observations over time.

Fair testing

In science, anything that might change during an experiment is called a **variable**. The thing that you deliberately change to see whether it affects the outcome of the experiment is a variable. Anything that is affected as a result of your change is also a variable.

In some situations, scientists design an experiment to try to answer their question. To be sure of the answer, they must make it a **fair test**. In a fair test, the scientists change one **variable** to find out what effect it has, and they are careful to keep all the other variables the same.

The quantity that you change is the **independent variable**. A quantity that changes as a result is called a **dependent variable**.

In a fair test, you change the independent variable, measure the dependent variable, and keep all the other variables the same. The other variables are called **control variables**.

Making a model

Sometimes it is not possible to do a practical investigation to answer a question – maybe what you are looking at is too big or small or dangerous to experiment on. Scientists can also make **models**. As well as helping to answer the question, a model can also be used to predict or to explain. Two types of model are a **physical model** and a **computer model.**

- A physical model is useful for very large-scale or small-scale systems. You may have used a physical model of the Earth and the Sun to explain why we have day and night.
- A computer model uses a computer program to find answers.

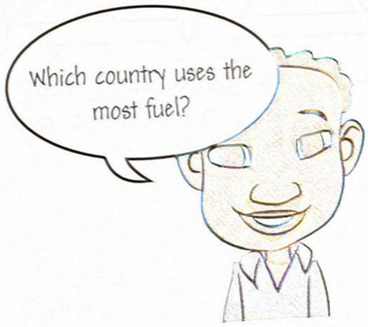
▲ *Thulani's question can be answered by making lots of observations of chimpanzees in their natural habitat. She would collect data and then choose the best way to display it.*

Field study

A **field study** is an investigation into plants or animals in their natural habitat. When doing fieldwork, it is important that you make observations without affecting what you are looking at.

A survey or regular observations or measurements

To answer some questions, a scientist might make lots of observations or measurements, or do a **survey**. They might do this over a long time, or all at the same time but in different locations. Sometimes a scientist uses data that other scientists have collected before.



▲ *Mosi's question could be answered by collecting data from lots of different countries and comparing them.*

Questions that science can't answer

Scientists cannot answer every question. They cannot answer questions about opinions, or questions for which the answer does not depend on data.

Science cannot answer Sanaa's question.

It could tell you:

- which phone battery lasts longest
- which phone can access web pages fastest.

But an investigation, a field study, observations, or a model will not tell you which phone is best. This is because different people will have different opinions about what is important: some people want a big screen, some people want a good camera, some people want a tough case.

▲ *Science cannot answer Sanaa's question.*

Thinking and working scientifically 2

Objectives

- Describe how to plan a fair test
- Describe how to plan other types of investigation

Planning and carrying out investigations

How do scientists get the data they need to find the answer to a scientific question? They need to make a plan to collect accurate and precise data.

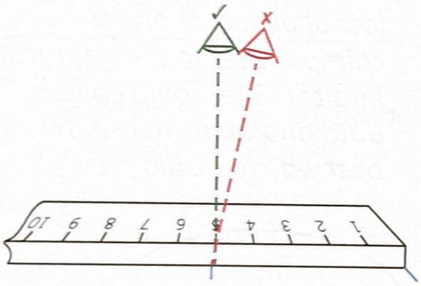
Planning fair tests

Before carrying out a fair test, you should make a plan. This helps to make sure that you have all the equipment you need to get useful results, and that you do not forget to do something, or do anything dangerous.

Selecting equipment

You need to select equipment that enables you to make measurements of your independent and dependent variables. You may also need equipment that will help you to control the other variables.

You should think about which equipment is most appropriate and how to use it appropriately. For example, you may need to decide whether a measuring cylinder or a beaker is better for measuring volume, or how to measure length accurately.



▲ *You should look straight at a scale to make an accurate measurement.*

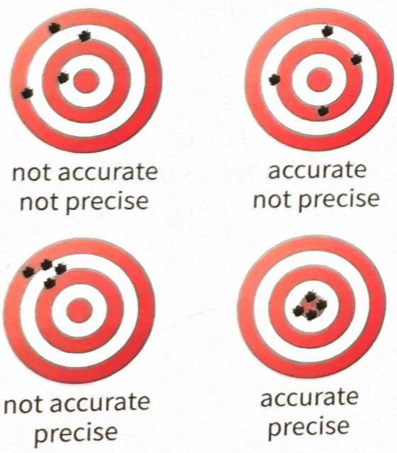
Accurate and precise data

The measurements you make in an investigation are called data.

It is important to collect data that is **accurate** and **precise**.

Accurate data are close to the true value of what you are trying to measure.

Precise data give similar results if you repeat the measurements. The repeat measurements in each set are grouped closely together. Precision is also determined by the smallest division of the measuring instrument you are using.



▲ *Readings can be precise but still not accurate.*

Reliability

You need to be confident that your data is **reliable** when you make a conclusion. Data is reliable if you have taken enough measurements. How many are enough?

- You need to have a big enough **range** of values of the independent variable. The range is the difference between the biggest and smallest values. If your range is not large enough you may realise after the investigation that you cannot be confident in your conclusion.
- You need to repeat your measurements. We usually make three **repeat measurements** for every value of the independent variable. You can do fewer, or more.
- You need to deal with **anomalous results**. An anomalous result is a measurement that is very different from the others in a set of repeat measurements and might be a mistake.

Thinking and working scientifically

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Collecting and recording data

How do scientists collect and record the data that they need to answer scientific questions?

Objectives

- Describe how to record data from a range of investigations
- Describe how to deal with anomalous results
- Describe how to calculate the mean (average)

Using tables

Measurements are easier to understand if they are in a clear table.

Write the name of the variable you change or compare in box X. If it is something you can measure, add its units.

x (units)	y (units)

Write the name of the variable you observe or measure in box Y. If you are measuring it, add the right units.

Use one line for each test you plan to do.

Write the names of any variables you control under the table, and add their values.

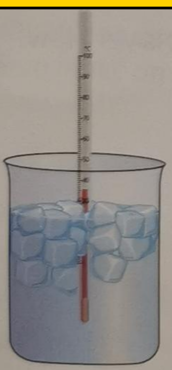
I kept these variables the same to make it a fair test:

e.g. volume of water = 50 cm^3

Using the correct units

If you use the wrong units for your measurements, your calculations will be wrong.

Thermometer



degrees Celsius

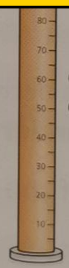
The units of **temperature** include **degrees celsius** (°C).

stopwatch

minutes and seconds

The units of **time** include **seconds** (s), **minutes** (min), and **hours** (h).

Measuring cylinder



cubic centimetres

The units of **volume** include **cubic centimetres** (cm^3) and **cubic decimetres** (dm^3).

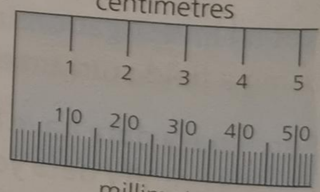
Balance / Scale

grams

The units of **mass** include **grams** (g), **kilograms** (kg), and **tonnes** (t).

Ruler / Measuring tape

centimetres



millimetres

The units of **length** include **millimetres** (mm), **centimetres** (cm), **metres** (m), and **kilometres** (km).

Recording repeat measurements and calculating the mean

In most fair tests you should find the value of the dependent variable more than once, and usually three times. This is a **repeat measurement**. You should record all your repeat measurements in your results table, always to the same number of decimal places.

When you have finished the repeated measurements, you should:

- Check for any **anomalous results**. Do not erase them.
- You can repeat the measurement, and if one is very different from the other two put a line through it and ignore it. Use your new measurements.
- When you are confident that you do not have any anomalous results, calculate the average (**mean**) of the measurements.
- To calculate the mean you add up the all the repeats and divide by the number of repeats.

For example, three students find the time it takes to draw a table. Jamil takes 75 seconds, Abiola takes 35 seconds, and Karis takes 73 seconds.

Abiola's result is anomalous because it is very different from the others. Jamil and Karis find out why. Abiola's table is very messy. She did not use a ruler. They decide to leave it out of the mean. The mean is $(75\,\text{s} + 73\,\text{s})/2 = 74\,\text{s}$.

Your average should be rounded up to the same number of decimal places as in the data.

x (units)	*y* (units)			
	1	2	3	Average

Draw boxes for three results for each test, and an average value. If a result looks anomalous, repeat it.

Recording measurements and calculated quantities

There are some experiments where you will need to calculate quantities using the measurements you have made.

In this situation, you should make another column in your table.

x (units)	Result 1 (units)	Result 2 (units)	*y* (units)	Average (units)

Draw boxes for three sets of measurements, three calculated values, and an average. If a result looks anomalous, repeat it.

Recording observations

In investigations where you are recording your observations, you need to adapt your table. In some cases, you may want to include images or diagrams, so the boxes in your table should be large enough to include them.

Thinking and working scientifically

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Objectives

- Describe how to decide which graph to plot
- Describe how to draw a bar chart, a line graph and a scatter graph
- Describe how to draw a line of best fit

Drawing graphs

How do you know which type of graph to plot? What is the best way to plot graphs? The way that you display the results of your investigation depends on the type of data that you have collected.

Types of data

If the values of the variable you change (x) are *words*, then x is a **categoric** variable. There is no logical order, like size, for the categories. Names are one example.

Variables like shoe size are **discrete** variables. They are numbers, but there are no in-between sizes. The number of paper clips in a pot or people in a room are discrete variables.

You can only draw a **bar chart** or a **pie chart** for data that include categoric or discrete variables.

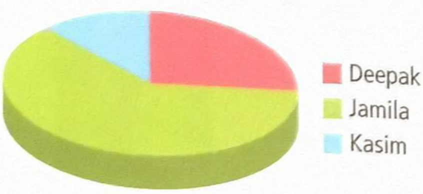
Other variables are **continuous** variables. Their values can be any number. Height, temperature, and time are continuous variables.

If the variables you change and measure are *both* continuous variables, display the results on a **line graph** or **scatter graph**.

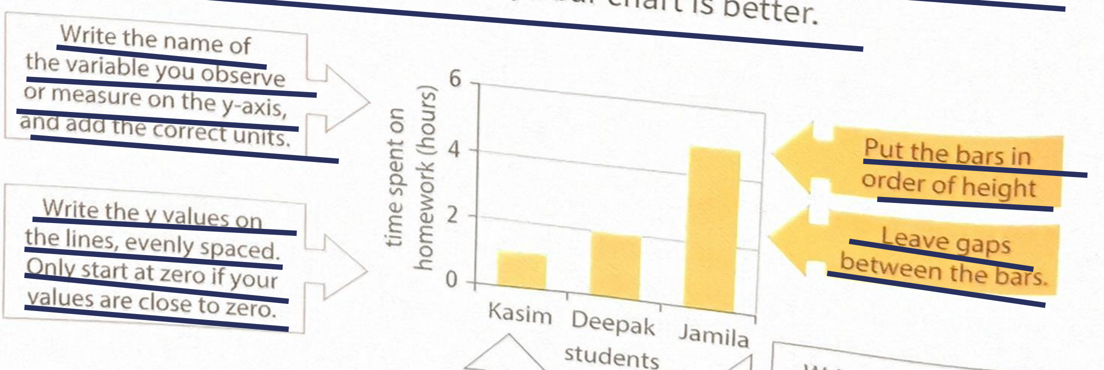
Pie charts and bar charts

Student	Time spent on poster (minutes)	Time spent on homework (hours)
Deepak	24	2.5
Jamila	54	4.5
Kasim	12	2.0

Deepak, Jamila, and Kasim research and design a poster together. The table shows the time that each of them spends. The pie chart drawn from the results helps you to see who did the most work on their project. Pie charts are useful for showing fractions of a whole. When you want to show data that do not add together, a bar chart is better.



▲ *Time spent on homework.*

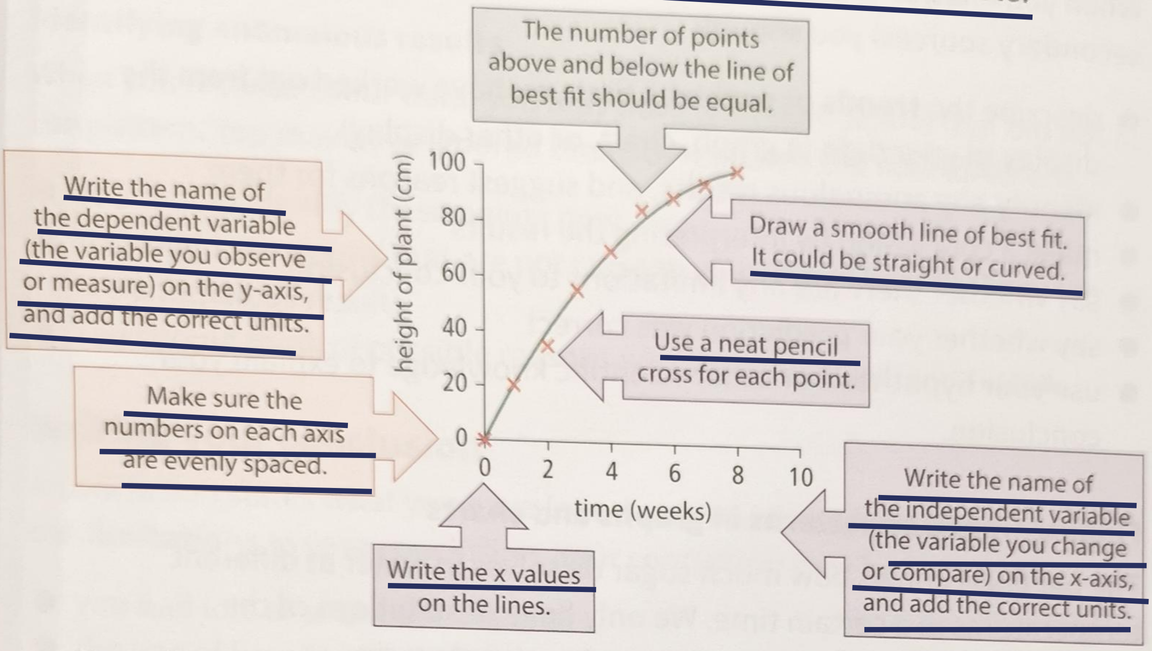


▶ *Time spent producing a poster together.*

Line graphs and scatter graphs

Drawing a line graph

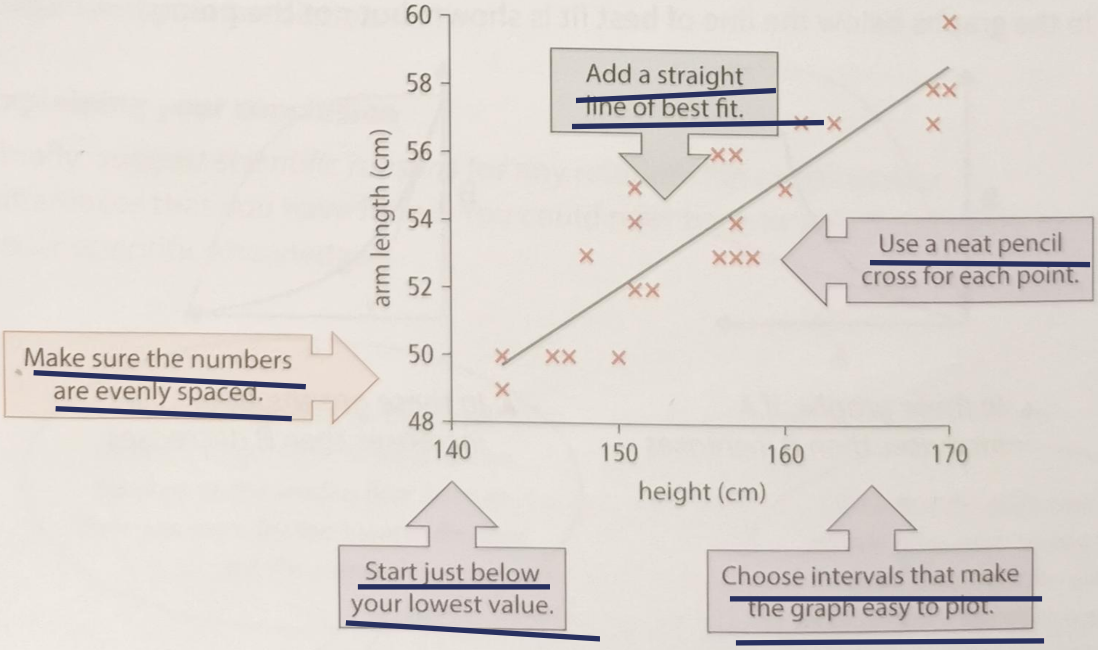
A line graph makes it easier to see the link between two continuous variables – the **independent variable** and the **dependent variable**.



▲ *Use a line graph for continuous variables when you think there is a link between them.*

Drawing a scatter graph

A scatter graph shows whether there is a **correlation** between two continuous variables. In the graph below, all the points lie close to a straight line. That means there is a correlation between them. If there is no correlation between the variables, then the points would be scattered all over the graph.



▲ *A scatter graph will show you if there is a correlation between two continuous variables.*

If you collect continuous data in a fair test investigation, you are trying to find out how one variable affects the other. You will usually plot a line graph.

In other investigations, you may be trying to see if there is a relationship between two variables. You will usually plot a scatter graph.

A line graph shows the link between two variables. You should draw a **line of best fit**. This is a line that goes through as many points as possible with roughly equal numbers of points either side of the line.

A correlation does not mean that one variable affects the other one. Something else could make them both increase or decrease at the same time. For example, if you plotted the number of ice creams sold in a town each day against the number of people going to the town swimming pool that day, you would see a correlation. This does not mean that getting wet makes people eat ice cream, or that eating ice cream makes people go swimming. It probably means that on hot days more people want to go swimming and to eat ice cream.