4 Scientific Investigations

Contents

LO 3, 4, 5 Nature of Science strand

Why it matters

Scientists work in a variety of ways to learn more about the world around us. They see patterns and relationships and carry out investigations to test their ideas. For investigations to produce meaningful data they must be conducted in an accurate, precise and reliable way.

Activity

Design an investigation: Joe says that he can't kick a soft football as far as a fully pumped football. 'Prove it,' his friends say. Design an investigation that Joe could use to prove that he is right.

4.1 A scientific approach to investigations

When scientists want to carry out an investigation they must identify whether they are collecting **quantitative** or **qualitative data**. Reliability, accuracy, precision, fairness and ethics must also be considered.

Quantitative data is based on measurements.

Qualitative data is data that is observed and not based on measurements, e.g. colour, smell and shape

Types of data: qualitative and quantitative

Fig. 1 Ecologists may gather qualitative and quantitative data when studying ecosystems such as forests.

Investigations involve collecting data, or information. Data that is based on measurements is called **quantitative** data. Data that is observed and not based on measurements, such as colour, smell and shape, is called **qualitative** data. For example, if a scientist is asked to investigate which plant species are found in a forest, they may collect qualitative and quantitative data. Their qualitative data would be a list of the different plant species present. Their quantitative data would be a measurement of the numbers of each plant species that are present.

Accuracy
How close a measured value is to the true value.

Precision
How close the measured values are to each other.

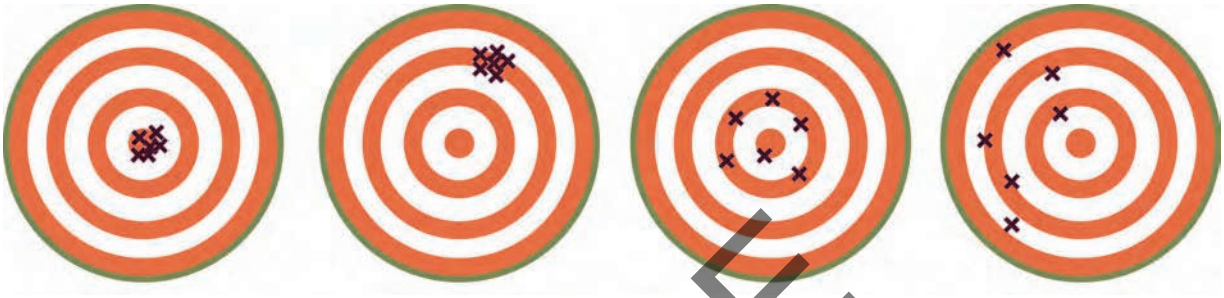
Reliability, accuracy, precision and fairness

In all types of investigation it is important to consider accuracy, precision, reliability and fairness.

Accuracy: When a measurement is close to the true value.

Precision: How close the measurements are to each other.

The following example of a target board illustrates the difference between accuracy (getting a bullseye, i.e. the true value) and precision (repeated shots are close to each other).



High Accuracy High Precision	Low Accuracy High Precision	High Accuracy Low Precision	Low Accuracy Low Precision

Fig. 2 Comparing accuracy and precision.

Reliability
Results that are similar every time the experiment is repeated.

Reliability: The results of an experiment can be called reliable if they are similar every time the experiment is repeated.

Fairness: A fair experiment should aim to have only one cause variable that changes. As far as possible all other variables should be kept constant.

Example To show reliability, accuracy, precision and fairness

Two students, Robert and Sarah, were asked to measure the length of a line. Robert used a ruler with centimetres and Sarah used a ruler with centimetres and millimetres. They each made three separate measurements.

This table shows their results:

Robert	19 cm	18 cm	18 cm
Sarah	19.8 cm	19.9 cm	20.1 cm

The actual length of the line was 20 cm.

Reliability: Both students repeated their measurements and obtained similar results so their results are reliable.

Accuracy: Sarah's results were close to the true length of the line so her results are accurate. Robert's results were not as close to the true length of the line so his results are not as accurate.

Precision: Sarah got results that were closer to each other so her results are more precise than Robert's.

Fairness: Two people conducted this experiment and therefore this is another variable. For the experiment to be fair only one person should take measurements.

Example **To show accuracy and precision**

Imagine a hurling player practising putting frees over the bar. If the player shoots with accuracy, his aim will always put the sliotar between the posts. If the player shoots with precision, his aim will always take the sliotar to the same location which may or may not be between the posts. A good player will be both accurate and precise by shooting the sliotar the same way each time and each time putting it between the posts. If you hit the upright every time, you are precise but not accurate!

Fig. 3 Sports players aim to be both accurate and precise.

Ethics

Ethics deals with moral principles. To work in an ethical way scientists have to consider if their actions are morally right or wrong. For example it is possible to design an experiment to see if drinking 20 cans of an energy drink within three hours would affect a person's health. However, if the scientist is already aware that energy drinks could have serious effects on a person's health, then the experiment may be considered to be unethical. The question of ethics is complex. For example, some scientists argue that testing on animals is important because it allows us to see the effects of various medicines and cosmetics on a living animal before testing them on humans. Other scientists argue that it is not ethical to intentionally cause harm to an animal for the sake of research. Many countries and scientific organisations have ethics committees to advise on whether a particular investigation is ethical.

4.2 Evaluating investigations

Scientists need to reflect on their results and evaluate them. The following are examples of questions that scientists can use to evaluate an investigation:

- Are the results accurate?
- Are the results precise?
- Is the investigation reliable?
- Do the results indicate a pattern?
- Can the scientist repeat the experiment and get the same results?
- Are one or two of the results different from a general pattern? What could be the reason for that?

Scientists often set up an investigation expecting to find one outcome but unexpected results must also be analysed. It is important for scientists to reflect on their method – What went right? What went wrong? What could be improved? Investigations are usually repeated to see if the same results are obtained and further investigations may be designed to gather more information.

4.3 Methods of investigation

When scientists want to investigate they need to choose the most suitable method of investigation. The methods that we will examine are: **controlled experiments**, **observational experiments, modelling** and **research**.

1. A controlled experiment

A squash player **observes** that the squash ball seems to get bouncier as the game continues. He also notices that the ball seems to get warmer. Based on this observation he forms a hypothesis that the bounce of the squash ball is affected by its temperature. This hypothesis can be tested by doing a **controlled experiment**.

Fig. 4 Why does a squash ball get bouncier as the game progresses?

A controlled experiment would be suitable because we could control the temperature and measure the bounciness. The hypothesis is that the increase in temperature causes the ball to become bouncier. Based on this hypothesis, there are two variables – temperature (the cause variable) and bounce (the effect variable). Both variables must be **measured** as carefully as possible.

This experiment could be conducted as follows:

Hypothesis: The bounce of the squash ball is affected by its temperature.

Type of data: Quantitative – measure temperature of ball and height of bounce.

Method

1. Drop a squash ball from 100 cm above the ground.
2. Measure how far it bounces back up.
3. Change the temperature of the ball and measure the bounce again.

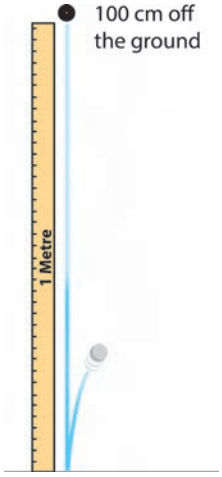


Fig. 5 Measuring how far a squash ball bounces back up

Fig. 6 Heating a squash ball

Results

Temperature of ball (°C)	10	20	30	40	50
Height of bounce (cm)	15	17	23	24	27

Communication of results

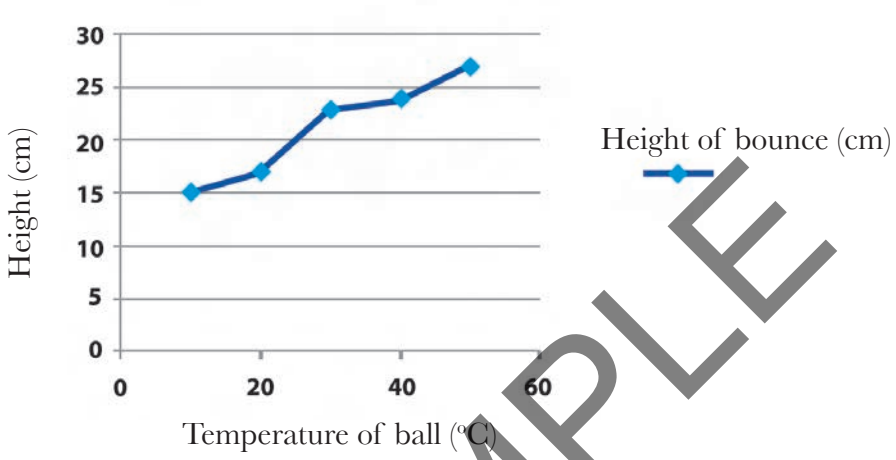


Fig. 7 Temperature of ball versus height of bounce.

Reviewing and reflecting on the experiment

In this experiment the bounce was only measured once at each temperature so it is not possible to tell if the results are **precise**. This investigation could be improved by making several measurements of the bounce at each temperature.

Temperature and bounce were changed in this experiment but other things could also change such as the height from which the ball is dropped and the surface on which it is bounced. These factors could affect the results of this experiment. To make sure they do not affect the results they must be kept the same throughout the experiment. This ensures that the experiment is **fair**.

2 (a). An observational experiment that collects qualitative data

A scientist was walking through a woodland and came across a rock which had moss growing on just one side. As she continued walking she noticed that all the rocks had moss only on one side. Using a compass the scientist found out that the moss was on the north face of the first rock. She then used her compass at each of the other rocks and found the same pattern. The moss only seemed to grow on the north face of the rocks. The scientist then went to other wooded areas in other parts of the country. She found the same pattern. Because the sun is mostly to the south in Ireland, she formed the hypothesis that moss does not grow in direct sunlight. Based on this hypothesis she made a prediction that in the southern hemisphere where the sun is mostly in the north, moss would be found growing mostly on the south face of rocks. She later found out that this is the pattern of moss growth in New Zealand.

The scientist conducted the experiment as follows:

Fig. 8 Does moss grow in direct sunlight?

Hypothesis: Moss does not grow in direct sunlight.

Type of data: Qualitative – the side of rock on which moss grows.

Method

1. Use a compass to find which side of the rock moss grows on in woodland.
2. Gather the same information from other woodlands in Ireland.
3. Research moss growth in the southern hemisphere.

Results

In Ireland moss grows on the north side of rocks, the side that does not get direct sunlight. In Australia moss grows on the south side of rocks, the side that does not get direct sunlight.

Communication of results

A written report of the scientist's findings could be completed. If it is new information her work may be published in a scientific journal.

Reviewing and reflecting on the experiment

The scientist formed a hypothesis and her experiment allowed her to gather data to support her hypothesis. She visited several sites in Ireland and further tested her hypothesis by obtaining information from a country in the southern hemisphere. Using an observational experiment meant that she did not have to disturb the woodland environment for her experiment.

2 (b). An observational experiment that collects quantitative data

A student noticed that the number of bird visits to a bird table with sunflower seeds was higher during cold weather. He decided to conduct an experiment to find out more about this.

Hypothesis: Garden birds feed more often at a bird table during cold weather.

Type of data: Quantitative – the number of bird visits to the bird table between 10 a.m. and 12 p.m. at two different temperatures.

Fig. 9 Do garden birds feed more often at a bird table during cold weather?

Method

1. Placed 500 g of sunflower seeds on the bird table on a cold day.
2. Counted the number of bird visits to the bird table between 10 a.m. and 12 p.m. and recorded the temperature.
3. Placed 500 g of sunflower seeds on the bird table on a warm day.
4. Counted the number of bird visits to the bird table between 10 a.m. and 12 p.m. and recorded the temperature.

Results

Temperature	Number of bird visits
2°C	23
15°C	16

Communication of results

The student may report his findings to his science teacher and check them with information available from Birdwatch Ireland.

Reviewing and reflecting on the experiment

The student used the same mass of sunflower seeds and observed the bird table at the same time of day, which helped to make his experiment fair. However, he only recorded one set of results for each temperature so he does not know if his results are reliable. He also only used one location. To improve his experiment he could repeat it at the same location and also carry out the experiment at different locations.

3. Using a model

Models can be used to show or demonstrate situations that are difficult to observe or are very large.

Physical models

A physical model is a structure that represents an object, system or process. For example, models of the human heart and brain are often used in schools to show students the different parts. An example of a physical model that shows how parts of a system interact is shown in Fig. 10 on the next page. This model of the human breathing system can be used to test the hypothesis that movement of the diaphragm causes inhalation and exhalation.

The model should be designed to represent the structure of the breathing system as accurately as possible. By moving the model 'diaphragm' up and down and observing the movement of air in and out of the 'lungs', evidence to either support or reject the hypothesis may be collected.

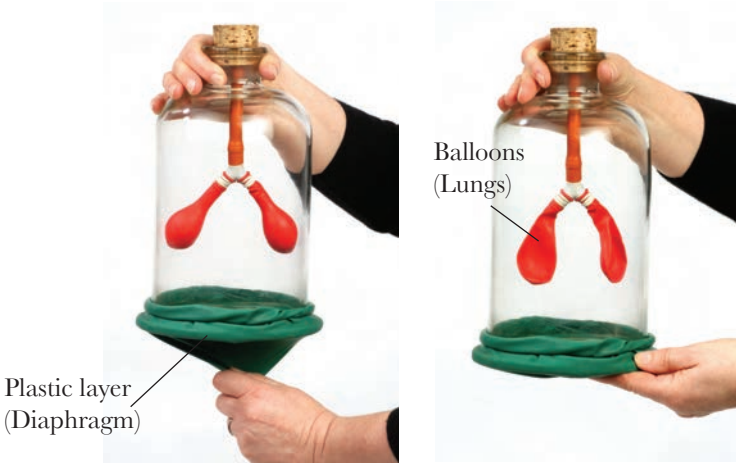


Fig. 10 A model of the breathing system.

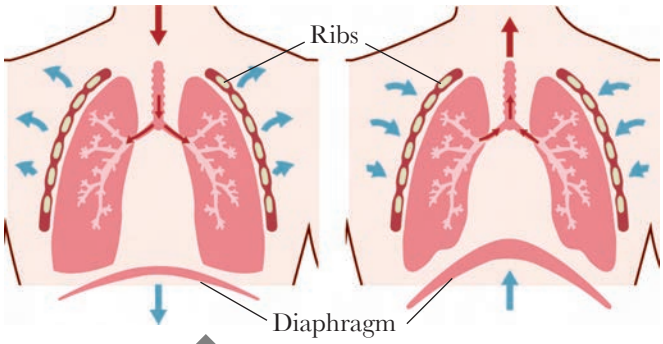


Fig. 11 The diaphragm moves down, the ribs move out and air is inhaled to fill the lungs. The diaphragm moves up, the ribs fall back in and air is exhaled.

Reviewing and reflecting on this model

This model is an appropriate way to demonstrate the breathing system because the balloons react to the movement of the plastic layer in the same way as the lungs react to the movement of the diaphragm. This is a suitable method as it is a simple and clear way to demonstrate the breathing system. However, the model does not represent the movement of the ribcage during breathing. To investigate the interaction of the diaphragm and the ribcage a more elaborate model could be constructed.

Conceptual models

Conceptual models can be used when there is a lack of physical evidence. For example models of the atom are based on observations and mathematical calculations. Conceptual models are used to test hypotheses about objects or systems that cannot be directly tested.

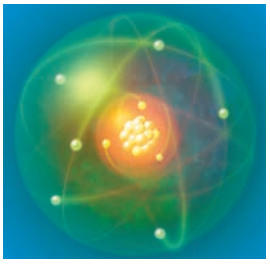


Fig. 12 Conceptual model of the shape of an atom.

4. Using research

Research is a way of collecting data from sources such as books and the internet.

A group of students wanted to find out about the effect on the circulatory system of a diet that is high in saturated fat. They decided to use the internet and their science textbook to gather information. They checked the information that they gathered by ensuring that at least two sources gave the same information. To present their findings they prepared a poster.

Reviewing and reflecting on this approach

A controlled experiment would not be suitable here as the students could not ask people to eat large amounts of food containing saturated fat in order to collect information. Observational experiments would also not be suitable as the effects of diets on the circulatory system can take a long time to show and medical observation would be needed to see the internal effects of a

diet high in saturated fat. Research on the internet was an appropriate method because scientists have been studying the effects of diets high in saturated fat for a long time and so there is a lot of information available.

4.4 Investigations in this book

Throughout this book you will see **Investigate this**. These ask you to design an investigation.
Some of them are **Extended Investigations**. These are more detailed investigations for you to research and design.

Activity Choosing suitable methods of investigation

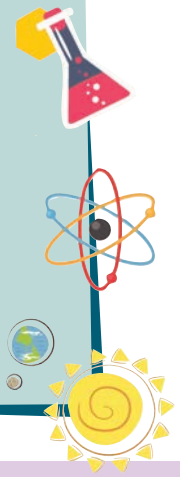
Take reliability, accuracy, precision, fairness and ethics into consideration when choosing a suitable method of investigation for each of the following hypotheses:

1. Some materials are more effective at conducting heat than others. Design an investigation to test this hypothesis.
2. Thick elastic bands can withstand more force than thin elastic bands before they break. Design an investigation to test this hypothesis. Give one method that could be used to collect qualitative data and one method that could be used to collect quantitative data.
3. Describe how you could investigate if the shape of an egg affects the hatch rate in chickens, i.e. whether they hatch or not.
4. Design an investigation to test if a new plant food will improve the growth of houseplants.
5. Describe a suitable method to investigate the orbit of Earth around the sun.

Chapter Summary

1. **Experiments, modelling and research** can be used to investigate scientific questions.
2. Science begins with **observations and questions**.
3. Scientists **suggest a reason** for their observations, identify a **hypothesis** and **decide on a suitable way to investigate**.
4. **Quantitative data** is data that is measured.
5. **Qualitative data** is data that is observed and not based on measurements, e.g. colour, smell and shape.
6. **Reliable** investigations give similar results every time they are repeated.

7. **Accurate results** are close to the true value.
8. **Precise results** are close to each other in value.
9. A **fair experiment** has only one cause variable that is changed.
10. **Ethics** deals with moral principles. To work in an ethical way, scientists must not only ask 'Can I?', they need also to ask 'Should I?'
11. Collected data can be used to **identify patterns and relationships** between variables.
12. Scientists **reflect** on their methods and results to **evaluate** them and to design further experiments.
13. **Research** is a way of collecting data from sources such as books and the internet.



Questions and Exercises

KC Key Concepts

Rewrite the following sentences in your copybook and fill in the blanks.

1. List three types of investigation that can be used to test scientific hypotheses.
   (a) _____ (b) _____ (c) _____.
2. When a scientist notices something it is called an _____.
3. Data that can be measured is called _____ data.
4. Data that is recorded without using measurements is called _____ data.
5. Investigations that give similar results every time they are repeated are described as _____.
6. Results that are close to the true value can be described as _____.
7. Results that are close to each other in value can be described as _____.
8. For each of the following set of results state whether they are reliable, accurate or precise. One or more descriptions may be possible:
   (a) Temperatures taken of a beaker of iced water: _____
   5°C 6°C 4°C 5°C

   (b) Measurements of a line that is 13.5 cm: _____
   11 cm 10.8 cm 11.2 cm

   (c) A golfer hits a ball the following distances: _____
   223 metres 221 metres 222 metres 221 metres

9. A variable is a factor that can _____ .
10. A factor that does not change in an experiment is called a _____.

K&U Knowledge and Understanding

1. Scientists must consider the ethical issues of investigations. What are ethical issues?
2. Suggest two advantages of reviewing and reflecting on experiments.
3. Scientists work to gather information to answer scientific questions. Scientists use experiments, modelling and research to collect information. Identify which method you think would be most suitable to investigate the following questions. Justify your answers.
   (a) Heart rate increases with exercise.
   (b) Drinking milk reduces the risk of osteoporosis in later life.
   (c) Burning coal causes smog.
   (d) Using plant food makes cut flowers stay fresher for longer.
   (e) Reducing the use of fossil fuels such as coal and oil will slow down global warming.

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