CONNECT
EDUCATION

THE ULTIMATE POSTER SAC GUIDE

Written by the best in the state.

James Bott, Jennifer Huang, Lizzie Wiles & Renata Galiamov

About this guide.

The scientific method is at the heart of all sciences. It provides a set protocol for scientists to ensure the collection of accurate, reliable, and valid data that can be used to draw sound conclusions about scientific phenomena.

And that's why practical investigation is given its very own Area of Study under Unit 4 of the 2017-2021 Study Designs. Although it's been included under the heading of Unit 4, you might sit this SAC as part of your Unit 3 or 4 assessment, or even both!

In class, you'll be required to conduct some sort of experiment based on one of the theories you've learnt, followed by a poster SAC where you'll write up a scientific report presenting your findings…

… Feeling queasy?

Well, that's why we've put together this guide to step you through all the different terminology and requirements of a scientific investigation, loaded with examples specific to each of Chemistry, Biology, Physics, and Psychology. Enjoy!

What's Inside:

The fundamentals 3
Laying out the scientific method 11
Subject-specific methodologies 15
Find more resources 39

About the authors.

This guide is designed by the award-winning team at Connect Education, who provide the best lectures, classes and notes to help you boost your ATAR.

James Bott received an ATAR of 99.65, as well as a perfect 50 in Physics.

Jennifer Huang received an ATAR of 99.90, as well as a perfect 50 in Biology.

Lizzie Wiles received an ATAR of 99.00, as well as a perfect 50 in Psychology.

Renata Galiamov received an ATAR of 99.95, as well as a perfect 50 in Chemistry.

Connect Education is the state's leading education company, helping thousands of students across the state learn and achieve more.

Sign up for more amazing free resources on the website.

THE FUNDAMENTALS

Variables

In an experiment, we only ever want to change one thing and observe the effect. The thing we change is called the **independent variable**. The thing it affects and that we measure is the **dependent variable** (it *depends* on the independent variable).

> **For example**, in **Chemistry**, say you wanted to investigate how surface area affects the rate of a reaction. The thing you're interested in (the thing you're changing) is the surface area of the reactants – you might have one beaker with a solid cube of reactant, and another beaker with powdered reactant. Hence, the 'surface area of the reactant' is the independent variable. To measure the rate of reaction, you might time how long it takes for the reaction to go to completion – this is the dependent variable.
>
> In **Biology**, you might want to investigate how a strain of bacteria cultivated in petri dishes responds to different types of antibiotics. Your independent variable, which you will be changing on purpose, is the 'type of antibiotic applied'; you might expose one dish of bacteria to Penicillin, and another to Tetracycline. The element of your experiment that is modified as a result of changing the independent variable – the growth/lack there-of of the bacteria on the petri dishes – is therefore your dependent variable.
>
> In **Physics**, you might conduct an experiment about how the height from which a ball is dropped affects the time it takes to hit the ground. What you, as the experimenter, are changing is the height the ball is dropped from; therefore, it is the independent variable. The result you are interested in is the time it takes for the ball to hit the ground, and so the time is the dependent variable.
>
> In **Psychology**, imagine you wanted to determine whether or not elaborative rehearsal improves recall, and if so, by how much. You could use an independent groups research design and get one group to memorise a list of 20 words for 5 minutes, and get the other group to use elaborative rehearsal (narrative chaining and acronyms) to memorise the same list for 5 minutes. Then, the next day, you could test them and see how many words they recall. In this case, since one group has used elaborative rehearsal while the other has not, 'the use of elaborative rehearsal to memorise a list of words' would be the independent variable, while 'the number of words correctly recalled' would be the dependent variable.

All other variables in an experiment are called **controlled variables**. These must remain constant, otherwise they could affect your results.

Any variable that *should* be controlled but is actually changing during your experiment is consequently called a **confounding variable**. The word 'confound' means 'to confuse, contradict, or refute', so essentially this means that a confounding variable stuffs up your entire experiment. This is because if you have

two variables changing, it's impossible to tell *which* variable caused the effect on the dependent variable. Thus, we must keep all variables constant *except* for the independent variable, allowing us to conclude that any effect observed is due to the independent variable alone. It's common scientific practice to identify all potential confounding variables before starting an experiment, and to ensure these are adequately controlled in order to produce valid data.

For instance, continuing with the previous **Chemistry** example, if you're investigating how surface area affects the rate of reaction, and you heated the beaker with the powder in it, but not the other beaker, how are you supposed to know whether it was the surface area or the temperature or *both* that affected the reaction rate? There's no way of knowing, because you've changed too many variables!

In **Biology**, a possible confounding variable in an experiment conducted to measure the effect of different antibiotics on bacteria would be to use different species of bacteria in each petri dish. Whether bacteria are susceptible or resistant to a particular type of antibiotic depends a whole lot on the characteristics of the bacteria itself, as well as the type of antibiotic applied. So, if different species or strains (subspecies) of bacteria are used, there is really no way to tell if the response to the antibiotic was due to the type of the antibiotic or the type of bacteria.

Again, continuing with the previous **physics example**, a possible confounding variable could be that different balls were used in different drops. This could have changed the drag of the ball, the force on the ball, way the ball spins, etc. Therefore, our results are invalid, as we don't know whether the independent variable – the height – or the extraneous variable – types of ball – was affecting the results.

In **Psychology**, there are a number of specific common confounding variables you have to look out for. These include: the placebo effect, the experimenter effect, order effect, individual participant differences, and use of non-standardised instructions and procedures.

The placebo effect occurs when there is a change in the response of the participant due to their belief that they are receiving some kind of treatment. They then respond in accordance with that belief, rather than due to the effect of the IV. This then makes it difficult to determine whether the change in the DV is from the change in the IV or from the participant's belief.

The experimenter effect occurs when there is a change in the participant's response due to the researcher's expectations, biases, or actions, rather than the effect of the IV. For instance, the experimenter might give away hints to one group, but not the other, causing the behaviour of the groups to be different.

Order effect occurs when performance, as measured by the DV, is influenced by the specific order in which the conditions, treatments, or tasks are presented,

making it difficult to ascertain whether the difference in performance was due to the IV or the order effect. For example, if you had to do the same puzzle over and over again during an experiment, you might get really good at that specific puzzle, which would then have an effect on the results. Alternatively, you could get bored of doing the same thing over and over again, which could also impact the results.

Individual participant differences are one of the most common confounding variables in psychological experiments. Differences in personal characteristics, such as age, sex, intelligence, personality, memory, educational background, ethnicity, mood, physical health, religion, and/or prior experience, can all have an influence on the measure of the DV if not carefully controlled.

Non-standardised instructions and procedures occur when there are differences between the procedures and instructions given to participants within or between groups which could lead to unwanted differences in the DV.

Qualitative and quantitative data

Different analytical techniques provide us with different types of data.

Qualitative data is information that cannot be expressed numerically; it can be expressed as words, pictures, colours, and so on.

For example, in **Chemistry**, observing the colour change of a solution as the reaction progresses is regarded as qualitative data; you can't really put a 'number' on it. In Unit 4, we also learn about HPLC, which provides us with qualitative information about the components present in a mixture, and IR spectroscopy, which provides us with qualitative information about the bonds present in a molecule.

In **Biology**, describing the type of growth exhibited by bacteria in a petri dish after treatment with antibiotics is collecting qualitative data. However, you can't assign a meaningful number to these observations. Even if you decided that the number '1' would represent 'lawn', '2' for 'colony' and '3' for 'no growth', ultimately these numbers are arbitrary in that they simply represent qualitative characteristics instead of having any numerical importance. There are many instances in biology where you might be asked to record and observe qualitative data. Examples other than the one above include observing whether a colour change occurs when iodine is added to starch solutions after various stages of enzymatic breakdown, or whether mammalian blood samples clot after having certain enzymes or factors are added to them.

In **Physics**, we may describe the colour of a light source as blue or red; this is qualitative data as there is no numerical value on it. Alternatively, we could describe the shape of a detraction pattern this light is creating, perhaps as 'many parallel lines'; again, because there is no numerical value, this would also be qualitative data.

In **Psychology**, qualitative data includes verbal descriptions from participants, audio or video recordings, or notes made by the researcher. For example, a participant describing their feelings over the last few weeks during a diagnosis would be considered qualitative because there are no numbers involved. This information can be very useful in psychological experiments because it provides a lot of specific, elaborate detail, but is a lot more subjective and difficult to interpret. Therefore, whilst it is often important to collect qualitative data, it is encouraged to support it with quantitative data as well.

Quantitative data, on the other hand, is numerical. These are statistics, measurements, amounts, and so on.

For instance, in **Chemistry**, measuring the volume of gas evolved during a reaction, or putting a beaker on a set of scales and measuring the 'mass loss' over time due to a gas being formed would be considered quantitative data because it is expressed as a number, has units, and is measurable. In Unit 4, mass spectroscopy provides us with quantitative information about the molecular masses of ions, and HPLC can provide us with quantitative information about the concentration of a substance.

In **Biology**, counting (or, more likely, estimating) the number of bacteria that have grown in each petri dish after applying different types of antibiotics is regarded as collecting quantitative data (you could go about this by determining approximately how many bacteria grow in each square centimetre of the petri dish, then multiplying that by the total area of the petri dish). Another common example of quantitative data being collected in biology is measuring how long it takes for a particular process to occur; for example, the number of minutes it takes for photosynthesising leaf discs to float to the surface of a water tank, or the number of days it takes for ethylene-exposed fruit to ripen.

In **Physics**, quantitative data tends to be favoured. In motion, any scalar or vector – such as distance or velocity, respectively – is quantitative (and direction must be included for vectors). While we could use qualitative data to describe light as blue, it is more useful to say it has a wavelength of 475nm, which is now numerical and therefore quantitative. Other types of quantitative data include: energy of all kinds, all forces, voltages, current, resistance, angles, and the list goes on. Physics is filled with quantitative data!

In **Psychology**, quantitative data includes raw scores, percentiles, average values, EEG graphs, and other forms of information that provide details in the form of numbers or graphs. For example, the number of hours slept or the score on a IQ test are both quantitative, as they can be measured and graphed. Quantitative data is always preferable in research as it provides more precision and ease of communication of results.

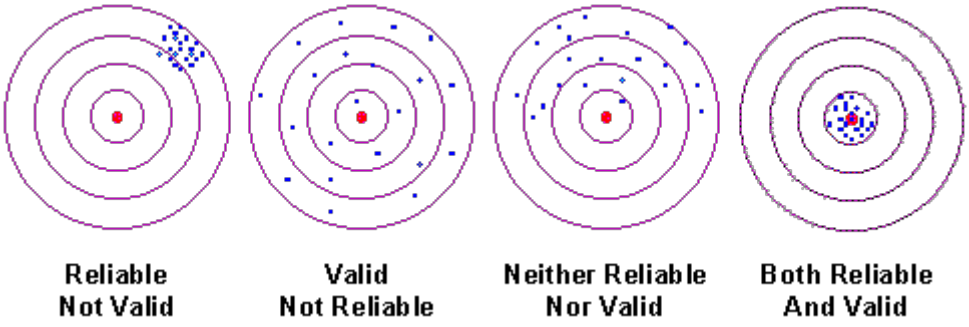
Accuracy, reliability, and validity of data

An experiment carried out methodically and meticulously should yield good data. "Good data" is accurate, reliable, and valid. Although these words might seem similar, they have slightly different definitions in science.

Accurate data refers to the 'exactness' of data. All measurements contain some uncertainty, but it's important we choose appropriate measuring instruments to ensure we get a reasonable degree of accuracy. For instance, you wouldn't measure a small distance with a metre ruler – you'd use a ruler with millimetres for greater *accuracy*.

Reliable data means that it is consistent and that we can depend on the results. We can achieve reliable data by repeating our experiment, ensuring that the results are consistent (i.e. similar).

Valid data means that it tests what it's actually supposed to be testing. An experiment that has an incorrect or partially incorrect method will not have valid data. For instance, if you perform an experiment and have a 'controlled' variable that's actually changing, then your data becomes invalid because you can't say for certain whether the results you obtained were due to the independent variable or this 'confounding' variable.



Experimental bias

The whole point of an experiment is to see the effect that an independent variable has on a dependent variable. We don't want anything interfering with the results, including **experimental bias**. This refers to our own expectations and predictions about what will happen in the experiment.

For instance, in **Chemistry**, you might suspect that one beaker will complete the reaction faster than the other, so you might stop the timer a tad earlier to ensure you get 'good' results. This is an absolute no-no. You must be responsible when taking measurements to ensure you obtain valid data.

We can minimise experimental bias by preferring quantitative data over qualitative data; numbers are more objective and harder to 'fudge', whereas qualitative data is open to interpretation, so is more easily influenced by bias.

Ethics, health, and safety guidelines

The experiments we conduct must be safe and have no long-term harmful effects.

When writing the method of an experiment, we must consider ethical guidelines, as well as health and safety guidelines. These rules and principles ensure that experiments are conducted appropriately, honestly and safely (both to organisms and to the environment).

Here are some things to look at:

- **For Chemistry**
  - Chemicals used – ensuring that chemicals are not carelessly wasted, and that they are disposed of safely.
  - Safety – if any dangerous chemicals are used, a risk safety assessment needs to be done. Consider the possible risks associated with using a chemical, and implement safety measures to avoid these risks. You can find heaps on information about characteristics of different chemicals and how they should be handled by googling the chemical's name and MSDS (Material Safety and Data Sheet).
    - For example, if working with a strong acid (like HCl), risks include severe burns to skin and eye damage if the acid is spilt. Safety precautions include wearing a laboratory coat, gloves, and safety glasses.
- **For Biology**
  - Organisms used – the use of organisms in biology – from a humble bacterium to a sheep's kidney used in dissection – is a very controversial topic from an ethical standpoint. Scientific communities are privileged to have access to other life forms for research purposes, and it is important that everyone respects the living or once-living thing they are able to study. Generally, it is inappropriate to take pictures of experiments involving organisms. You should also make sure to treat and dispose of any creature sensibly and with consideration.
  - Safety – there are experiments in Biology – such as the antibiotics experiment described above – which may involve some risks to the experimenter's health and safety. In general, it is good practice to tie long hair back, wear gloves and a lab coat when conducting Biology experiments involving chemicals or living/once-living things. These are general Biology safety precautions, but there are also plenty of methodology-specific ones that you must discuss in your SAC.
- **For Physics**
  - Safety – In physics the primary safety hazards come from poorly designed or implemented experiments. Safety hazards can include physical harm/bruising (or worse) when using weights for forces, as well as eye damage from using laser lights.

- **For Psychology**
    - Confidentiality – it is important that participants of psychological studies have the right to privacy. As such, participant names and personal details should not be published with any results from the study.
    - Voluntary participation – participants must voluntarily consent to be involved in a study, and it must be ensured that those who choose to not participate do not experience negative consequences.
    - Withdrawal rights – participants must be able to withdraw from the study at any time without negative consequences, and also have the right to withdraw their results once the study has finished, all without explanation.
    - Informed consent – the experimenter must inform participants of the nature and purpose of the study beforehand, including details such as the procedure, risks and/or disadvantages of participating, information of the collection and publication of results, and participant's right to withdrawal and confidentiality. Informed consent must be documented, usually by a consent form that is signed by the participant. If a participant is underage, the parent/guardian must give consent.
    - Debriefing – once the study is complete, participants must be debriefed. This includes giving participants an opportunity to ask questions about the study or to clear up any misconceptions they may have. It also gives the experimenter an opportunity to provide participants services to treat any distress that may have been caused by the study.
    - Deception – sometimes the use of deception is necessary in psychological studies if we want to get accurate results (sometimes we can't tell participants everything, otherwise it would cause them to act differently). As such, sometimes deception can be used in studies, as long as it does not cause significant distress to participants. Participants must be debriefed when deception is used.

Sources of error and uncertainty

No matter how meticulously we plan our experiment, sources of error and uncertainty are inevitable.

Systematic errors are those associated with an equipment fault. These errors affect all data in the same way because the same equipment has been used to make all measurements.

- For instance, in **Chemistry**, using a burette that has incorrect calibration lines results in systematic errors. Similarly, using a scale that has an in-built error will result in all measurements being affected.
- In **Biology**, a typical systematic error would be using substances that have expired or been contaminated so that they don't do their job. For example, using out-of-date Penicillin in an experiment testing the effectiveness of various antibiotics, or using denatured enzymes instead of functioning ones,

would affect *all* data collected. Another common systematic error is the use of scales with in-built errors when recording the weight of something.

- In **Physics**, the time between two points can only be measured to a certain accuracy, even with the use of computer help. Additionally, distances can only be measured to a certain precision, and weights are only rated to a certain accuracy as well, so forces will not necessarily be accurate. Another systematic error could be how accurate a voltmeter or ammeter is. Essentially, any recording or measuring device will introduce some level of systematic error.

Random errors occur due to chance. They're mainly due to the human factor. Difficulties in judging measurements lead to slightly different results. This is why it is crucial to repeat experiments; taking the average of many results will produce more accurate data.

- In **Chemistry**, in a titration, you might get titres with different volumes because you may have stopped the titration at different end points, since it's difficult to judge when the indicator changes colour.
- In **Biology**, random errors may stem from having trouble judging when or if a process – the ripening of a piece of fruit or a colour change in an iodine test – occurs. Again, these are associated with flaws in your human judgement, which are really hard to prevent.
- In **Physics**, returning to the example of the ball being dropped and recording the time taken for it to fall, there are several random errors. Timing would likely be conducted by hand, and in all likelihood the person timing would 'miss' both when the ball is dropped and when the ball lands by a statistically significant amount (i.e. the person timing will almost certainly not be able to 'start' the timer exactly when the ball drops, and 'stop' the timer exactly when the ball lands).
- In **Psychology**, random errors are usually due to individual participant differences, such as differences in age, gender, ethnicity etc. This is why it's important to have a representative sample, which helps 'average out' all these differences.

Sources of uncertainty arise due to measurement limitations; i.e. limitations associated with the level or precision an instrument has. For instance, when you use a 30 cm ruler to measure the size of something, you can only measure to the nearest millimetre, because that's the smallest increment on the rule. If we note the size to be 50 millimetres, then we know that the size must be between 49.5 and 50.5 mm due to rounding principles. But we can't say for *certain* what the size is; it could be 49.7 mm or 50.1 mm, and so on. Therefore, we say that the size is 50 mm with $\pm$0.5 mm uncertainty. In general, the smallest increment on an instrument is called the **least count** (e.g. 1 mm from our example), and the **uncertainty** is calculated as **plus/minus *half* of the least count** (e.g. $\pm$0.5 mm uncertainty).

LAYING OUT THE SCIENTIFIC METHOD

All laboratory reports must be written in a consistent format to ensure scientists around the world can communicate information effectively.

Some general rules when it comes to writing scientific reports are:

- **Write in third person:** don't use personal pronouns like "I", "me", and "our". Instead, use expressions like "it was found", "it was concluded that", and "the results indicated that".
- **Write in past tense:** think about telling someone about something that has already happened.
- **Be concise:** don't waffle on about stuff. Less is more.

Title

The title of your poster/scientific report should be in the form of the question you're investigating (for inspiration, look at the headings used in VCAA Study Designs for different Areas of Study – all of them are written as questions). For example, in Chemistry, you could have a title such as, "How does the surface area of a solid reactant affect the rate of a reaction?".

Introduction

In your introduction, VCAA requires you to explain the reasoning behind doing the investigation you're doing. Your teacher might like you to write a proper introduction in paragraph form, explaining the relevant theory and providing a bit of context behind the experiment. If your teacher *does* want you to do this, make sure you cite the references you use (see *References* below for more information).

In addition, the introduction would include a statement about the aim of the experiment, as well as a hypothesis (you might like to put the aim and hypothesis as subheadings in your introduction).

Aim

This is a short summary of what you're trying to achieve in the experiment. A good way to start is: "To investigate the effect of… on…"

e.g. Chemistry: To investigate the effect of surface area of a solid reactant on the rate of a reaction.

e.g. Biology: To investigate the effect of different types of antibiotics on the growth and reproduction of *E. coli* bacteria.

e.g. Physics: To investigate the effect of the drop height of a ball on the time it takes for the ball to land.

e.g. Psychology: To investigate the effect of different types of rehearsal (elaborative and maintenance) on recall ability.

Hypothesis

This is your prediction about what will happen in the experiment. An effective way to word it is: "It is hypothesised that if… then…".

A 'because' can be included if you'd like.

e.g. Chemistry: It is hypothesised that if the surface area of a solid reactant is increased, then the rate of reaction will increase due to the increased frequency of collisions, as per Collision Theory.

e.g. Biology: It is hypothesised that if Penicillin is applied to a petri dish containing *E. coli* bacteria, then there will be no bacterial growth.

e.g. Physics: It is hypothesised that if the ball is dropped from a higher height, then the time taken for it to land will increase at a rate approximately proportional to the square root of the drop height.

e.g. Psychology: It is hypothesised that if participants use elaborative rehearsal, they will be able to recall more words than those who use maintenance rehearsal.

Method

This should be a short summary of what you did in your experiment. Check with your teacher as to whether they'd like it written as numbered steps, or as a paragraph. Be sure to mention the equipment you used; the amount of time spent heating, cooling, waiting, and so on; and the quantities/concentrations of chemicals you used, if applicable.

The VCAA Study Designs state that the methodology should be "authenticated by logbook entries" – although this sounds fancy and somewhat scary, all it means is that, during your experiment, you will need to record data and note down any observations you make, or any changes you make to the method provided.

In the method is also where you would mention the relevant health, safety, and ethical guidelines you've followed in the investigation. Refer to the *Ethics, Healthy, and Safety Guidelines* section under *The Fundamentals* for some subject-specific examples of factors to consider.

Results

In this section of the report, you simply present your results. It's customary to present a table of data, as well as a graph (if applicable). Check with your teacher about whether they'd like your tables and graphs to have headings, or whether they'd prefer to see a table heading (above the table) and figure caption (below the graph) – this is convention in published scientific reports. Either way, be sure to include labels for the axes in your graph, and include the units of measurement in both tables and graphs.

Check out the examples below:

Table 1: Time taken for reaction to reach completion, varying the surface area of the solid reactant

Condition	Time (seconds)			
	Trial 1	Trial 2	Trial 3	Average
Solid cube	59.0	58.3	61.2	59.5
Chopped up pieces	36.7	35.9	36.2	36.3
Powder	4.5	4.9	4.1	4.5

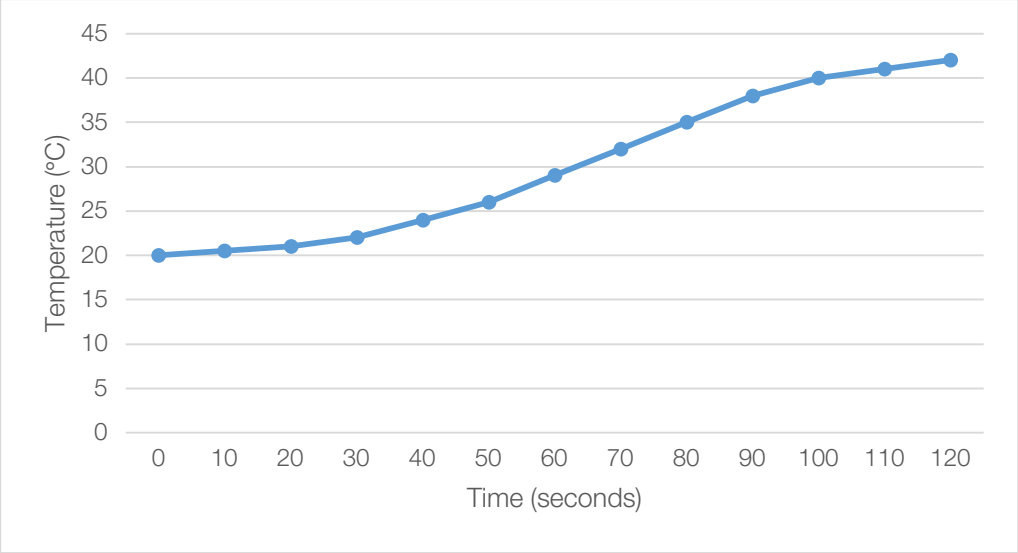


Figure 1: Temperature of the reaction solution over time

It's also customary to write a sentence or two, summarising the results. For instance, a sentence you could write about Table 1 is: "The results show that the solid cube took the longest to react, while the powder was the quickest." A sentence you could write about Graph 1 is: "The temperature rose slowly for the first 20 seconds, then began to increase more dramatically, and plateaued after 100 seconds." Make sure you **don't** talk about *why* you got the results you did (save that for the discussion!)

Discussion

In your discussion is where you **link your results to your aim, your hypothesis, and chemical theories**. Think about how your results 'answer' your aim.

- Do your results support your hypothesis, or should you reject it?
- How do the results relate to what you already know about the concepts or theories underlying the experiment?
    - For instance, did the results support what you know about Collision Theory in **Chemistry**, about cellular processes in **Biology**, about Newton's Laws of Motion in **Physics**, or the Atkinson-Shiffrin model of memory in **Psychology**?

This is also the time to mention any drawbacks or limitations to the experiment.

- Did you get any unexpected results? If so, why do you think this occurred?
- Were there any sources of error? (See *Sources of error and uncertainty* under *The Fundamentals* for more information and examples)
- What were the sources of uncertainty?
- Most importantly, how could you remove these errors and improve these uncertainties in subsequent experiments?
- In **Psychology**, can you generalise your results?

Conclusion

Here's where you sum up the experiment and briefly state what you found.

A good way to start is: "The aim of the experiment was to… By measuring the ____ in response to changing ____, it was found that…. (state what the results showed about the aim). This supported (or did not support) the hypothesis."

Check with your teacher to see how much they'd like to see in the conclusion; different people have different views about what should and shouldn't be put in the conclusion.

References

When discussing theories or quoting from the internet or the textbook, it's important to cite/reference where you obtained the information from. There are different referencing models – the most common being the Harvard referencing system, and the APA 6th edition referencing system – and different ways to reference different sources. Ask your teacher whether or not they will be marking you for including references – more often than not, you will have to include at least one reference to get the mark for this section of the report. A fantastic resource you can use to learn how to cite properly is http://library.unimelb.edu.au/cite.

SUBJECT-SPECIFIC METHODOLOGIES

While the scientific method applies to all branches of science, there are particular methodologies used by certain scientific disciplines more than others. In this section, we delve into some of the common research and analytical techniques used in chemistry, biology, physics, and psychology.

Biology

In Biology, experiments exploring cellular processes and biological change over time will be assessed as part of Area of Study 3, Unit 4. You are most likely to be assessed on properties of selectively permeable membranes, bacterial responses to specific antibiotics, or electrophoresis and bacterial transformation.

Unlike in Chemistry Units 3 and 4, the methodologies used in Biology experiments are not so consistent; there are often many ways to observe the same relationship between your independent and dependent variables. However, there are definitely some errors that apply to each of the broad categories of experiments above.

Exploring membranes

In this experiment, you may observe what types of biologically important molecules and ions, such as water, salt (sodium chloride), glucose and proteins, can or cannot pass through a semipermeable membrane, such as dialysis tubing.

For this experiment, it is most effective to present the data you collect as a table, which might start off like this:

The Permeability of Biologically Significant Salts and Molecules Through a Semipermeable Dialysis Membrane

Test for	Reagent	Permeable/ nonpermeable	Results
Starch	Iodine	Non-permeable	• Fluid inside the dialysis tubing (where the starch was originally placed) turned blue • Fluid on the outside of the tubing showed now colour change

Note that a semipermeable membrane is totally different from a selectively permeable membrane!

- **Semipermeable:** semipermeable membranes are not generally found in living things. This type of membrane differentiates what substances can or cannot pass through it based mainly on the size of the particle. Think of it like a sieve, which will let through small particles but traps the bulky ones.
- **Selectively permeable:** selectively permeable membranes are found surrounding cells (the plasma membrane) as well as certain organelles, such as

the nucleus (nuclear envelope). This type of membrane differentiates what substances can or cannot pass through it based on the needs of the cell or the organelle, and is therefore a lot more selective than a semipermeable membrane.

You will most likely be investigating semipermeable membranes in your SAC with the assumption that they act similarly to selectively permeable membranes for practical purposes. However, as selectively permeable membranes are much more biologically significant, you should definitely consider comparing the two membrane types in your discussion.

In your discussion, try and address points such as:

- Particles can only passively diffuse across a semipermeable membrane. On the other hand, a selectively permeable membrane, with specific transport proteins and the ability to perform endo- and exocytosis, can allow for passive diffusion of particles, but also active transport and bulk transport.
- Relate the properties of a selectively permeable membrane with its biological function: its specificity means that it can meet the needs of a cell or an organelle much more adequately. Along the same vein, think about why a semipermeable membrane will do poorly in a biological context.
- Small molecules, such as salts and water, are able to move across semipermeable membranes through diffusion and osmosis respectively, whilst large molecules like starch and big proteins might not be able to do so quite as easily due to their bigger size. Think about how the hydrophobic core of the plasma membrane affects the movement of salts and water across it, as well as the contributing effect of membrane proteins and means of bulk transport.

Safety

- Follow general laboratory safety protocols.
- Experiments such as this one use particular chemical reagents, such as iodine (which is fairly toxic). It is important to research the MSDS safety sheet for any chemical substances used and quote safety protocols listed there if asked to discuss safety.

Errors

The errors arising from this experiment will largely include systematic errors that you really can't control, such as the substances you are given to test being out of date and hence not passing through the semipermeable membrane properly, or built-in errors in scales.

This experiment requires you to have a good understanding of the methodologies and scientific language associated with microbiology. You will likely be expected to describe types of growth exhibited by bacteria when exposed to different types of antibiotics, and be required to back up your observations with biological facts.

You should be talking about the bacterial response to antibiotics as well as types of bacterial growth exhibited in each petri dish, and what this means in terms of their level of resistance to the antibiotic.

What an antibiotic does

Having an understanding of the function of a general antibiotic will really help you grasp the principles of this experiment.

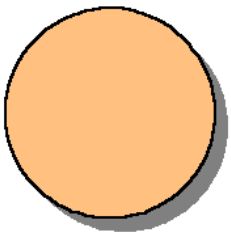
In nature, antibiotics are used mostly by other organisms, such as fungi, to kill bacteria which compete with them for food. They do not affect our own body cells because they target cellular characteristics that are essential to bacterial function, but which our cells might not have.

Antibiotics target bacteria by:

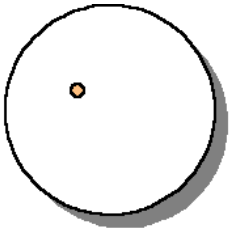
- Disrupting the synthesis of bacterial cell walls. This stops bacteria from successfully dividing because new cell walls need to be grown for bacteria to separate successfully. Penicillin operates this way.
- Other antibiotics, such as erythromycin, disrupt the activity of bacterial ribosomes, which are structurally distinct from ours.

Types of bacterial growth and what they mean:

- **Lawn:** bacteria cover the entire petri dish surface. This type of growth only happens when the bacteria are totally happy in their environment. This wouldn't be seen if the bacteria exhibited *any* level of sensitivity to the antibiotic.
- **Colony:** bacteria grow in small circular colonies. Each colony is made up of a single original group of surviving bacteria surrounded by their offspring. This type of growth is seen when only some bacteria are susceptible to the antibiotic.
- **No growth:** surprise, surprise, 'no growth' means that bacteria don't grow at all! This means that the bacteria are very vulnerable to the antibiotic and are totally eradicated.



bacterial "lawn"



single colony

Safety

These tips are not only important for keeping you safe in a laboratory environment. Discussion of method-specific safety measures is an especially important component of an experimental report or poster on an experiment involving microbes, so keep a few of these in the back of your mind when writing your SAC.

These safety requirements are also relevant for gel electrophoresis and bacterial transformation.

- No eating or drinking inside the laboratory to prevent the micro-organisms you grow from contaminating your food or drink.
- Sterilise all equipment, surfaces and materials. Waste materials that have come into contact with bacteria should also be autoclaved (exposed to high heat and pressure to thoroughly kill off remaining traces of bacteria).
- Wash hands with disinfectant lotion before and after the practical.
- Make sure to write clear labels on everything to avoid mixing up petri dishes containing bacteria and those with no growth.
- Ideally, clean up spills with antiseptics.
- Individuals with immune disorders or allergies to the antibiotics used should not participate in the practical activity.

Errors

The errors arising from this experiment will largely include systematic errors that are, again, out of your control. For instance, the bacterial culture may have been killed prior to the experiment through exposure to inadequate storage conditions, leading to all petri dishes showing ‘no growth’.

Bacterial transformation is the incorporation of foreign DNA into bacterial cells. Because the bacteria transformed with the foreign DNA reproduce asexually and, hence, replicate this foreign DNA repeatedly, this genetic engineering technique is used to create many copies of a target DNA strand.

Vectors

A **vector** is a molecular vehicle used to transfer DNA from one organism to another. The vector used in bacterial transformation is a **plasmid**, a small circular strand of bacterial DNA that fulfils the three essential criteria of a good vector:

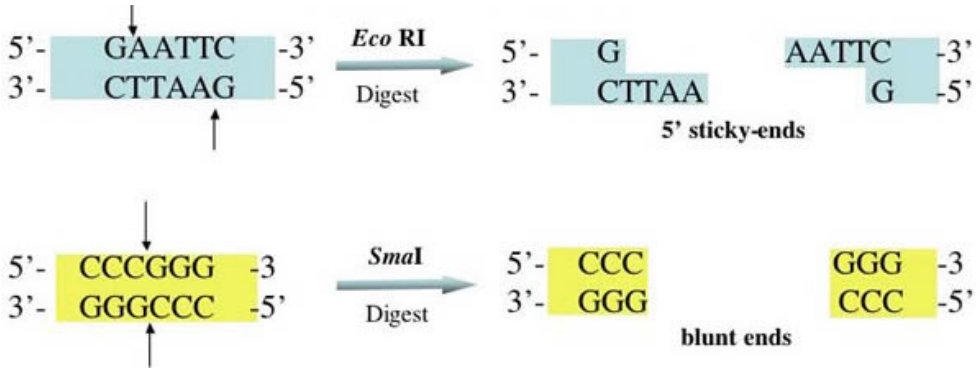
- Can replicate inside the target organism
- Have one or more recognition sites for a restriction enzyme
- Contain a genetic marker that, when expressed, indicates that the vector has successfully transferred DNA into the target organism

Restriction enzymes

In nature, **restriction enzymes**, also called restriction endonucleases, are found in bacteria and act as an immune defence mechanism against viruses that attack them (bacteriophages).

These enzymes break phosphodiester bonds in DNA at a specific nucleotide sequence 4-8 bases long (**recognition sites**). Each restriction enzyme recognises a specific recognition site. Recognition sites are palindromic so that regardless if the enzyme is 'scanning' the sense or the antisense strand of DNA, it is still able to cut the DNA at the same site.

Restriction fragments have either **sticky ends** (overhanging, exposed nucleotide bases created when restriction enzymes cut the two DNA strands unevenly) which can only anneal to a complementary and specific nucleotide sequence cut by the same restriction enzyme, or **blunt ends** (restriction enzymes cut the two DNA strands evenly, resulting in no overhanging, exposed bases) that are non-specific.



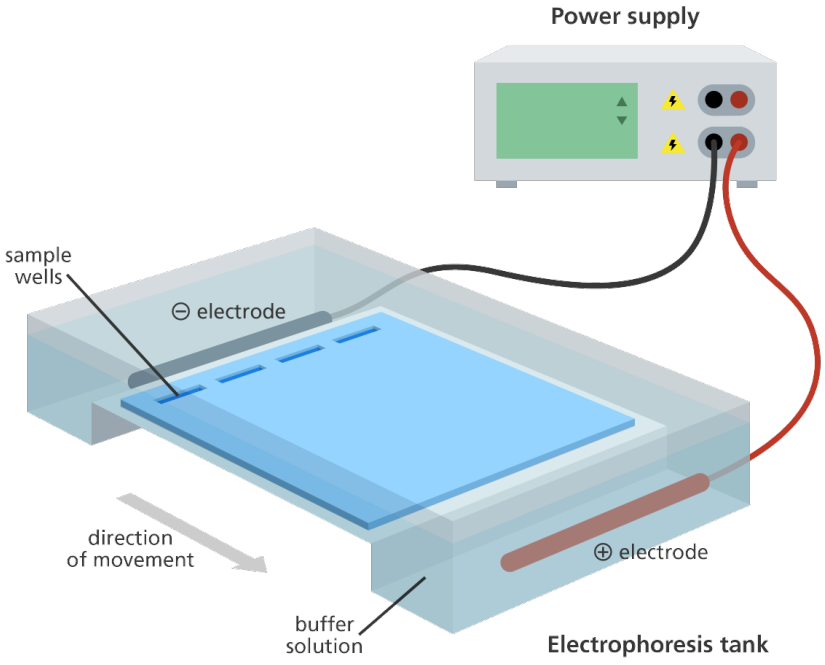
Methodology of gel electrophoresis

Gel electrophoresis is used to separate DNA fragments of different lengths. This is useful when you want to isolate a particular fragment of DNA of a known base pair length for use in your bacterial transformation – for example, a fragment containing the specific target gene you want to insert into your bacteria's genome to make it a transgenic organism.

This is one of the very few specific, fixed methodologies you might encounter in Unit 3 and 4 Biology, with associated errors.

Elements of a gel electrophoresis analysis:

- The **gel** refers to the agarose in the electrophoresis tray that provides a porous matrix for the DNA to move through. Because it provides a degree of physical resistance, smaller DNA pieces can move further through it than larger ones in a given time, allowing DNA fragments to be separated by size.
- In addition, the agarose also contains a **fluorescent dye** that intercalates (lodges and gets stuck) into the double helical DNA fragments, allowing them to glow and be visible under UV light.
- The gel is submerged into a **buffer solution** containing ions to make it conductive as well as chemicals to maintain the stability of the DNA fragments.
- On one end of the gel is a **cathode** (negative electrode) and on the other end is an **anode** (positive electrode). All DNA carries the same slight negative charge due to the negative phosphate groups in its phosphate-sugar backbone. Therefore, when a current is applied to the gel, the DNA molecules will be repelled from the cathode and will diffuse towards the anode (at different rates according to their sizes).



There are 3 main steps to gel electrophoresis:

1. The gel is divided into several lanes, one for each length of DNA you want to isolate, as well as a marker 'ladder' lane containing DNA fragments of known base pair lengths.
2. After electrophoresis, this **ladder lane** acts as a standard to which restriction fragments in the experimental lanes can be compared to infer their length.
3. DNA fragments resulting from each restriction digest are mixed individually with loading dye so that DNA is visible when pipetting it into the well. The voltage is turned on for a period of time to allow fragments to diffuse and separate in each lane.

Finally, the entire gel is viewed under UV radiation. The restriction fragments, stained with fluorescent dye, will glow and become visible.

Errors

Action	Effect on gel electrophoresis
Running the electrophoresis for too long	Smaller, faster travelling DNA fragments will run off the end of the gel and be lost.
Using a very high voltage or current when doing the electrophoresis analysis	Smaller DNA fragments will run off the end of the gel and be lost.
Connecting the positive electrode to the negative terminal and the negative electrode to the positive terminal instead of the other way around	This will force the current to flow backwards, causing your DNA samples to not move from the wells.

Methodology of bacterial transformation

There are 4 main steps of bacterial transformation, which your teacher or demonstrator may carry out differently depending on the institution and the specific materials available.

1. Creating a recombinant plasmid

   Use a restriction enzyme to isolate the desired gene (target gene). Treat a plasmid vector with the same restriction enzyme, and mix the cut plasmid and target gene. The sticky ends produced will be complementary and anneal together. Add DNA ligase, which seals the insulin gene into the plasmid vector with phosphodiester bonds, creating a recombinant plasmid.

2. Transforming bacteria

   Incorporating a recombinant plasmid into bacteria is usually done by heat shock, which involves heating the bacteria suddenly and briefly. This alters the structure of the bacteria's cell membranes, making them more permeable and receptive to plasmids.

3. Isolating transformed bacteria

   Only about 1% of the bacteria subjected to heat shock will take up the recombinant plasmid and be successfully transformed. To distinguish the transformed from the untransformed bacteria, test for the expression of the gene marker present in the plasmid vector. For example, if the gene marker coded for penicillin resistance in bacteria, only transformed bacteria will survive exposure to penicillin.

4. Reproduction and gene expression of transformed bacteria

   Allow transformed bacteria to perform asexual reproduction in a nutrient-rich environment. As they do so, they clone and express the desired target gene.

Safety

In addition to the safety precautions listed for the experiment observing bacterial responses to antibiotics, other safety measures need to be taken into account when participating in this particular practical.

The fluorescent dye that intercalates into the DNA fragments in the gel electrophoresis procedure disrupts the DNA double helical structure, and can cause mutations during DNA replication. Therefore, it is a mutagen, and it is very important that it does not come into contact with any part of the body. Laboratory coats and gloves are therefore more important than ever in this experiment!

Chemistry

In Chemistry, you'll most likely conduct an experiment related to Collision Theory or Equilibrium Law (or both), galvanic/electrolytic cells, volumetric analysis, or calorimetry (or possibly instrumental analysis, but this is less likely).

Collision Theory or Equilibrium Law (Le Chatelier's Principle)

Experiments related to Collision Theory or Equilibrium Law will usually require you to measure the change in concentration of a substance over time to see how various factors affect the rate of reaction or the position of equilibrium. There are many ways of doing this, including:

- Measuring the volume of a gaseous product produced over time (e.g. by measuring the height of the gas in an inverted test tube).
- Measuring the 'mass loss' of the reaction beaker over time due to a gaseous product being evolved (the gas will escape the solution in the beaker, causing the mass of the beaker to decrease).
- Noting the colour change of a solution or gaseous mixture over time, or timing how long it takes for a solution to become cloudy/clear.
- Measuring the pH change of a solution over time (for reactions involving acids/bases) by using indicators (noting colour change), or a pH meter.

The key is, in the discussion of your report, to relate what you observe back to Collision Theory or Le Chatelier's Principle, depending on your experiment.

> **For example**, say you're investigating the effect of surface area of a solid reactant on the rate of reaction (i.e. the time it takes for the solution to become clear to the observer, for example). Imagine you find that increasing the surface area (using a powdered reactant as opposed to a solid lump) decreased the time it took for the solution to become clear (i.e. it increased the rate of reaction), then you need to explain how this confirms what you've learnt in Collision Theory. For instance, you could say something like, *"It was found that increasing the surface by using powdered [name of chemical] in Trial 2 decreased the time it took for the solution to become clear by four times, indicating that the reaction rate had increased four-fold. This confirms what is proposed by Collision Theory, which states that increasing the surface area of a solid results in more exposed particles, thereby increasing the frequency of collisions between reaction particles and, thus, increasing the rate of reaction."*

Errors in rates/equilibria experiments

The nature of these experiments can be very different, but here are some ideas for errors that may be applicable to your experiment:

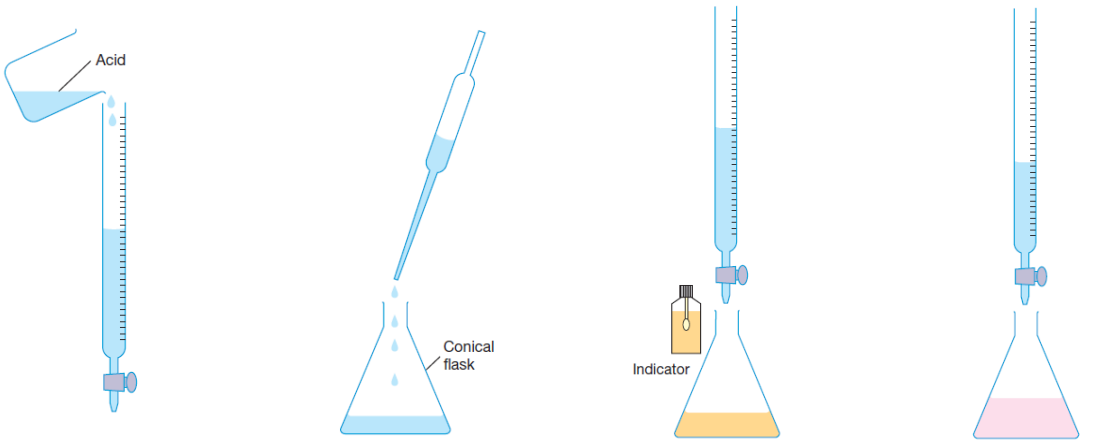
- Random errors associated with using slightly different masses/volumes of reactants in different trials of the experiment. Using slight more reactant in a

particular trial would increase the frequency of collisions between those particles, leading to an increased rate of reaction in that trial.

- Random errors related to human error; some methods for measuring rates of reaction/equilibrium position involve noting colour changes over time, which is a subjective measure that is open to interpretation. When one person may think the colour has changed or that the solution is clear, another person may not, leading to different 'times' being recorded.
- Experimenter bias, which arises when you predict/expect certain results for each trial, and this influences your measurements. For instance, you might know that in an experiment investigating how surface area of a solid affects rate of reaction, Trial 1 (which uses a solid lump) will take longer to become clear than Trial 2 (which uses powder), so you might wait a few more second for Trial 1, but be very quick to stop the timer in Trial 2.

Volumetric analysis

Volumetric analysis helps us find the concentration of an unknown solution using the technique of titration: this involves reacting a volume of a solution of unknown concentration with a solution of accurately known concentration. We can then use stoichiometry to determine the concentration of the solution of interest.



Fill a burette with the solution of known concentration.	Use a pipette to deliver an aliquot of the solution of unknown concentration.	Add indicator to the conical flask, which will tell you the end point.	Record the titre delivered by the burette at the end point.

Equivalence point vs. end point

An important idea to grasp is the difference between the equivalence point and end point. The **equivalence point** is when the reactants have been mixed in the exact molar ratio shown by the chemical equation. The **end point** is when the indicator changes colour, signalling to you to stop the titration because the equivalence point has been reached.

Primary standards

To obtain the best results, we use **primary standards** to create our solutions of accurately known concentration. Primary standards are chemicals with certain properties/features that make it easy to create a solution with an accurate concentration. Primary standards must:

- Be pure – do not get easily contaminated
- Be stable – do not decompose, absorb water or react with the atmosphere
- Be cheap and abundant – for practical purposes
- Have a high molar mass – enables the moles to be calculated accurately

A common primary standard you will come across is sodium carbonate, Na_2CO_3. It is used as a base in acid-base titrations.

Concordant titres

To ensure accurate results, it's important that you obtain **three concordant titres**, and find the average of these. Concordant means that the difference between the smallest and largest titre should not exceed 0.1 mL. (This is because each drop from the burette is 0.05 mL, so if you have done the titration accurately, all your titres should be within one drop of each other.)

> **e.g.** You obtain the following titres: 10.01, 10.15, 9.98, 10.05 mL
>
> The three concordant titres you should use are: 9.98, 10.01, 10.05 mL because the difference between the maximum and minimum titre in this trio is 0.07 mL, whereas if you had chosen the other trio (10.01, 10.05, 10.15), the difference would be 0.14 mL, which is too inaccurate.
>
> The average titre is: $\frac{9.98+10.01+10.05}{3} = 10.01\ mL$

Calculating the concentration of the unknown solution

By the end of a titration, you will know the following pieces of information:

- The balanced chemical reaction equation
- The volume (aliquot) of unknown solution you used
- The concentration of the known solution (primary standard)
- The volume (titre) of known solution required to reach the end point

Remember, the thing that connects all species in a chemical reaction is the molar ratio. So, whenever you do titration calculations, your aim is to find the moles of the known solution first. Then, you can use the molar ratio to find the moles of the unknown solution. Since you know the volume (aliquot) you pipetted of the unknown solution, you can use $C = \frac{n}{V}$ to find the concentration of the unknown solution.

In summary:

1. Find n(known solution) using C x V(titre)

2. Use the molar ratio in the chemical equation to find n(unknown) in aliquot
3. Find concentration of unknown in aliquot using C = n(unknown)/V(aliquot)
4. Account for any dilutions

Errors in volumetric analysis

When considering how an action may have affected the end calculation of the unknown concentration, it's useful to think about how the action affects the volume of the titre. After all, it's the volume of the titre and concentration of the standard that we use to determine the moles of substance of unknown concentration.

In direct titrations, bigger titres than needed lead to overestimations of concentration, while smaller titres than needed lead to underestimations.

Action	Effect on titre	Overestimation/ underestimation of concentration
Rinsing water is left in the burette	Burette solution is diluted → bigger titre needed	Overestimation
Rinsing water is left in the pipette	Aliquot is diluted → smaller titre is needed	Underestimation
Rinsing water is left in the conical flask	No effect. We've already done the required volume measurements; adding water won't affect the number of moles	No effect
Competing ions in the conical flask also react	More titre is used up	Overestimation
You go past the end point	More burette solution is put in the conical flask than needed → bigger titre	Overestimation
Indicator changes colour too soon	Titration is stopped before the equivalence point → smaller titre	Underestimation

Calorimetry

A **calorimeter** is a thermally insulated container, usually holding water. It's important that it is well insulated to ensure accuracy; we do not want any heat released by the reaction taking place inside the calorimeter to be lost to the environment.

There are two key steps to calorimetry:

1. **Find the calibration factor of the calorimeter.**
   We can't just assume that the amount of energy needed to raise the temperature of the calorimeter by one degree Celsius is going to be the same as that for water. Instead, we must figure out the 'specific heat' of the calorimeter – we call this value the **calibration factor**.

   - We do this by running a known amount of electricity through the calorimeter and measuring the temperature change.
   - The energy provided by the electricity is given by the formula:

     $$Energy = voltage\ (volts) \times current(amps) \times time\ (seconds) = VIt$$

   - The calibration factor is given by energy divided by temperature:

     $$Calibration\ factor\ (J^oC^{-1}) = \frac{energy}{temp\ change} = \frac{VIt}{\Delta T}$$

2. **Place a known amount of reactants inside the calorimeter and measure the temperature change. Use the calibration factor and temperature change to find the energy released from the reaction.**
   Since food *releases* energy, the temperature of the calorimeter should increase. Knowing the calibration factor, we can determine the amount of energy released.

   - Since the units for calibration factor are J $°C^{-1}$, we can calculate the energy released by multiplying the calibration factor by the temperature change caused by the reaction:

     $$Energy\ from\ reaction = calibration\ factor \times \Delta T$$

   - Energy content is often given as J g^{-1} or kJ g^{-1}, so once you have found the energy released by the reaction, just divide energy by mass of reactant to find the energy content:

     $$Energy\ content\ (J\ g^{-1}\ \ or\ \ kJ\ g^{-1}) = \frac{energy}{mass\ of\ food}$$

Note: be careful with the temperature changes. Make sure you clearly identify which temperature change is associated with calculating the calibration factor, and which temperature change is associated with the reaction.

Errors in calorimetry

When considering errors in calorimetry, it's useful to think about how the error will affect the temperature change of the calorimeter, and that will help you figure out how, in turn, the energy content will be affected (since energy content is calculated from energy, which is based on the temperature change of the calorimeter).

Action	**Effect on ΔT**	**Overestimation/ underestimation of energy content**
Putting more reactant/food in the calorimeter than what you've recorded	More reactant → more energy released from combustion → greater ΔT However, you *think* that there's actually less reactant in the calorimeter than there really is	Overestimation
Faulty thermometer that does not accurately increase as temperature increases	Smaller temperature change recorded → lower energy calculation → lower energy content calculation	Underestimation
The calorimeter is not perfectly insulated	Some heat escapes from calorimeter → lower temperature change → lower energy calculation → lower energy content calculation	Underestimation

Physics

In Physics, experiments tend to be more varied, with the possibility for many different experiments to be done by different students in the one class. Additionally, while some other subjects may focus familiarizing students with new equipment and techniques, Physics often favours student input into the design of the experiment and generally have simpler methods. However, there are some general experiment types likely to be consistent.

Young's Double Slit experiment

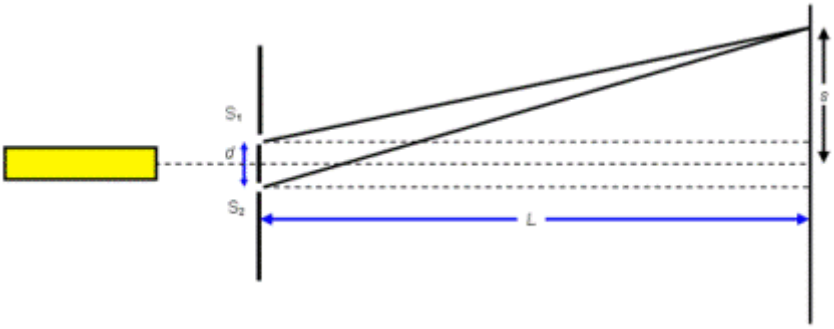
The Young's double slit experiment is used to show the wave-like nature of photon. The experiment will require you to shine a light of a single wavelength, usually from a laser, through two thin slits and to examine the interference pattern produced. This can be done in a few different ways:

- The interference pattern can be drawn over in pen/pencil, so that it no longer moves.
- The distance between the gaps can be measured.
- It can be placed next to a ruler.

The key part of the discussion must explain how the experiment implies light (photons) has wave-like properties. The explanation will need to involve:

- A description of the interference pattern;
- An explanation as to why the light would interfere, highlighting that, like waves, light has a wavelength;
- An explanation of how there is constructive interference at the bright bands and destructive interference at the dark bands; and
- An explanation of how this can then be used to reinforce that light has wave-like properties.

Additionally, you should discuss what effects of the diffraction pattern, which can be summarised as shown below:



- $s \propto \frac{\lambda L}{d}$

Where

- S is the distance between the two bright bands (or two dark bands) on the screen
- λ is the wavelength of the light
- L is the distance to the screen
- d is the distance between the slits

The effect each variable tested had on the diffraction pattern should be explained, as well as the uncertainty, since reading the diffraction pattern is notoriously difficult.

Errors in this experiment

- Random errors related to human error that arises due to the difficulty of measuring the small distances in this experiment. This human error would decrease the accuracy of the recording of the interference pattern.
- Random errors related the to the accuracy (or should we say, the in-built **in**accuracy of the equipment); these are usually much smaller than the human error.

Motion experiments

While motion-based experiments may be conducted in all sorts of different ways, investigating all different types of motion, there are some general principles overarching them all.

Generally, these types of experiments will have several different independent variables with corresponding dependent variables. Usually, a graphical representation of the data can be made.

These graphs need to be related to the **relevant equations**. A good way to check whether you've chose the appropriate graph is to see whether you can derive a formula from it (thus confirming a formula/theory you've learnt in class). If the results do not follow the equation/formula as expected, then you need to provide reasons for why it doesn't follow the curve as expected. Remember to think about:

- random errors – i.e. human error involved in timing/measuring distances
- systematic errors – i.e. in-built errors of measurement instruments
- errors in the method – i.e. essentially, did you stuff up?
- simplifications/assumptions that may not have been reasonable to make. For example, we may assume air resistance is negligible, but in some experiments it may have a profound effect.

Likely you will be asked to do many or at least one experiment based on electromagnetism. Generally, the method of these experiments are simple and well-explained and it is your knowledge of Lenz's law, Faraday's law, generator etc. that is being tested.

Discussion

In the discussion, focus on the laws related to the experiment and explain how the experiment (hopefully) supports these laws.

For example:

> *"It was found that [increasing the current] had the effect of [increasing the force on the wire]. This confirms what was expected as [$F = nBiL$, and number of turns, magnetic field strength, and length of the coil was kept constant, while current was increased, suggesting that the force would also increase], which was observed."*
>
> Note: everything in square brackets can be replaced to suit a different experiment and law.

Often a diagram will be needed to explain these types of experiments in terms of the direction of the force, and/or the right-hand slap/grip to be used.

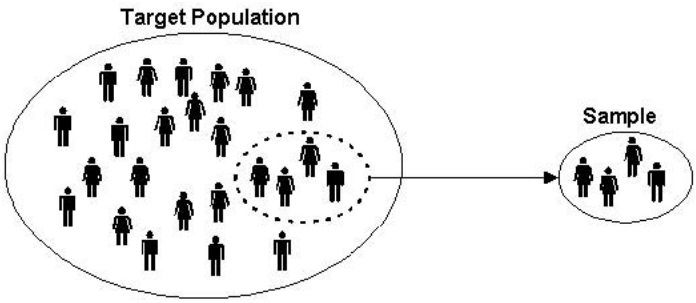
Psychology

One of the most important aspects of designing a psychological study is ensuring that correct research methods/techniques are used. This makes sure that you minimise confounding variables to give the most reliable data possible so that it can be generalized to the wider population (as this is the main goal of psychological research…what's the point in doing it if you can't generalize it to the population!?).

Sample vs Population

To begin with, let's look at the difference between the sample and the population of interest.

When doing a study, in general researchers will be studying a **population** of people; for example, the population of Victoria, Australia, Monash University Students, or VCE students. However, it would be too difficult and/or expensive to experiment with every single member of those populations. So, in order to do a study, experimenters will take a **sample,** a smaller group of people from that population that are to represent the wider population.



In summary…

- **Population** – the term used to describe the larger group of those being studied.
- **Sample** – a subset of the population that is chosen to represent the larger group of those being studied.

But how do we select our sample?…**participant selection** methods!

Participant Selection

Once we have decided on our population of interest, we must decide on an appropriate way to select our sample, ensuring that our sample represents the wider population as best as possible. We can do this a number of ways…

Convenience Sample

This involves selecting participants who are readily available, without any attempt to make the sample representative of the population. For example, if your population of interest was VCE students, a convenience sample would be just picking 50 VCE students from your school because it's easy.

Strengths	Weaknesses
• Cheap, easy, and fast. • Useful for preliminary testing before an *actual* experiment takes place because it gives an idea of what the responses could be.	• Sample is not representative of the wider population. • Produces a biased sample. • Findings from studies using convenience sampling cannot be generalised to the wider population (because the sample is not representative).

Random Sample

When random sampling is used, every individual in the population has an **equal chance** of being selected to be a participant in the study. This can be done using random name generators, putting names on slips of papers and drawing them from a hat, tossing a coin, etc. Random samples become more reliable as the sample size increases, as there's more likelihood the sample will be more representative of the wider population. Smaller sample sizes that use random sampling are not as reliable.

Strengths	Weaknesses
• Ensuring every member of the population has an equal chance of being selected makes it more likely that the sample will be representative of the wider population.	• Time consuming and could require a lot of effort to ensure every member of the population has an equal chance of being selected. • If sample size is small, the sample could end up not being representative.

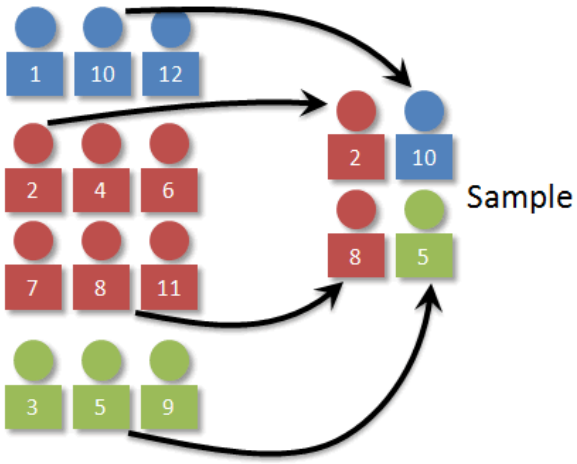
Stratified Sample

This involves dividing the population into distinct subgroups (strata), then selecting a separate sample from each stratum in the same proportions that they appear in the population.

Random Stratified Sample

This is essentially exactly the same as a stratified sample aside from the fact that in this sampling method, it's ensured that the participants are randomly selected from each stratum to minimise bias.

The procedure involves identifying all of the people within each stratum, then randomly selecting samples of proportionate size from within each stratum. For example, if you were doing an experiment on students from a particular secondary school and there were 100 year 7s, 8s and 9s, 80 year 10s; 70 year 11s; and 60 year 12s, you would choose 10 year 7, 8, and 9s; 8 year 10's; 7 year 11's, and 6 year 12's to represent the population.



Strengths	Weaknesses
• The sample can be assumed to be truly representative of the wider population and free from bias. • Results are more likely to be able to be generalised.	• Very time consuming and expensive.

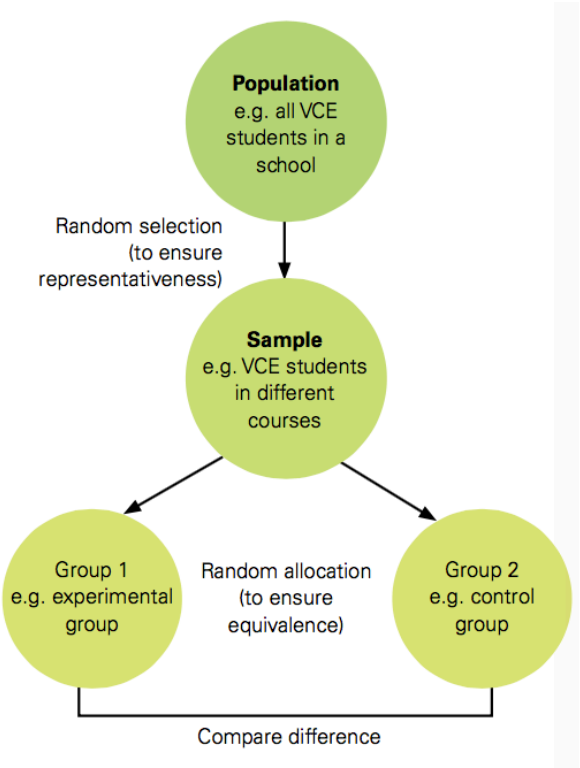
Now we've selected our sample to represent the wider population of interest we must now allocate our sample into control and experimental groups… this is called **participant allocation.**

Participant Allocation

We have our sample and we now need to allocate participants into experimental and control groups.

- **Experimental group** – this is the group that is exposed to the experimental conditions, i.e. the independent variable.
- **Control group** – this is the group that is exposed to the control conditions, i.e. they are not exposed to the independent variable.

Allocation to the experimental or control group is usually random to ensure there is equivalence in the groups. This can be done a number of ways, for example simply numbering off participants.



Make sure you don't get confused between **random selection** and **random allocation**. Random selection is used to select participants for the study, whereas random allocation is used once the participants have been selected to place them into the experimental or control group.

A researcher must also decide on what type of experimental design they want to use for their experiment, so we now move on to… **research design.**

Experimental Research Design

There are three research designs that can be used during an experiment; independent groups, matched participants, or repeated measures.

Independent Groups

- Two groups involved in the study – one is exposed to the control condition and one is exposed to the experimental conditions.
- This design involves people being randomly allocated into either the control group or experimental group.

Strengths	Weaknesses
• Using random allocation will usually result in an even spread of characteristics between groups, especially if the sample size is large. • No order effects. • Experiment can be conducted on one occasion (unlike in repeated measures) which will minimise participant drop out (participant attrition).	• Group allocation could end up being biased if the sample size is small. • Could result in an uneven spread of characteristics between groups which could influence results (confounding variable).

Matched Participants

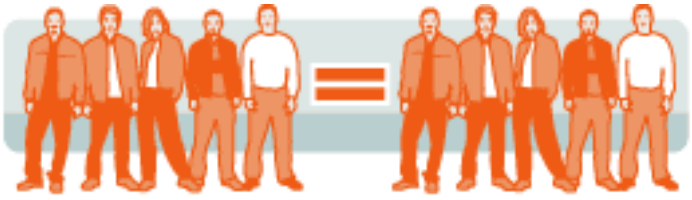
- Two groups involved in the study – one is exposed to the control condition and one is exposed to the experimental conditions.
- Instead of participants being randomly allocated to a group, they are matched specifically on characteristics that are key to the study or that may affect the results, e.g. age, intelligence, sex, etc.

Participants aren't the same people, but they share similar important traits.

Strengths	Weaknesses
• Eliminates potential confounding variables due to individual participant differences. • Experiment can be conducted on one occasion (unlike in repeated measures), which will minimise participant drop out.	• Time consuming to have to do pre-testing to match up pairs. • Pre-testing can lead to the order effect (participants will have practiced the task before the actual experiment). • If one person in the pair drops out of the study, then the other person also has to drop out.

Repeated Measures

- One group of particpants involved in the study – exposed to **both** the experimental and control conditions.
- Instead of having a control and experimental group, the **same group** of partcipants act as both groups and are used in both scenarios.



The same group of people are used in both conditions.

Strengths	Weaknesses
• Individual participant differences are 100% eliminated as the same individuals are being used. • Gives the experimenter control over participant variables that may have influenced results, such as differences in IQ or personality. • Smaller sample size needed.	• Order effect could definitely be present if not carefully controlled by using counterbalancing. • Counterbalancing can be time consuming as participants may need to come back a few days/weeks later. • Higher participant drop-out (participant attrition) due to boredom/fatigue/loss of interest in the study.

As well as the conventional experimental designs, there are other methods of undertaking psychological investigation. It is important to be aware of these different types of studies and to understand what they are used for.

Case Study

An intensive, in depth investigation of some behaviour or event of interest in an individual or small group. They help develop a detailed profile of a client that is very important during research of an individual. One of the best known case studies is of Phineas Gage.

Observational Study

An observational study involves the collection of data by watching carefully and recording the behaviour as it occurs. It is used only when behaviour is clearly visible and easily recorded. Often naturalistic observation is used, whereby the researcher will view the behaviour in an inconspicuous manner so as not to influence the behaviour of the participants.

Self Report

Involves the participants giving written or spoken responses to questions, statements or instructions presented by the researcher. These can be in the form of a diary, responses to questionnaires, surveys or interviews, etc.

Cross-Sectional Study

A cross-sectional study can be seen as taking a ‘snapshot’ in time of different groups and then comparing the variables from that single point in time. For example, you might test how memory is influenced by age, so you could get groups of people aged 10, 20, 30, 40, 50, 60, and 70 to all do a memory test. These results then provide a snapshot of differences in the variable (memory) in the different groups. This may seem like an experiment, but do not be fooled…it is not! (You are not manipulating/changing an independent variable on purpose; you are simply observing differences between different individuals.)

FIND MORE RESOURCES

Only at Connect: innovative, top-tier resources, classes and lectures that are transforming education and driving results for thousands of VCE students.

Resources

Find amazing resources such as this online.

Lectures

Learn more about lectures in the city, which are an eye-opening, results-changing experience.

Learn more about lectures at schools, which reimagine the way schools such as Balwyn High School have approached exam revision and topic workshops.

SuperClasses

Get tutoring from the best in the state, along with amazing weekly resources.

CONNECT

EDUCATION