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VCE Biology ¾

Experimental Design & Practical Investigation [5.1]

Workbook

Outline:

Study Design:

Investigation Design

Biological concepts specific to the selected scientific investigation and their significance, including definitions of key terms.

Characteristics of the selected scientific methodology and method, and appropriateness of the use of independent, dependent and controlled variables in the selected scientific investigation.

The accuracy, precision, reproducibility, repeatability and validity of measurements.
The health, safety and ethical guidelines relevant to the selected scientific investigation.

Scientific Evidence

The nature of the evidence that supports or refutes a hypothesis, model or theory.

Ways of organising, analysing and evaluating primary data to identify patterns and relationships including sources of error and uncertainty.

Authentication of generated primary data through the use of a logbook.

Assumptions and limitations of investigation methodology and/or data generation and/or analysis methods.

Science Communication

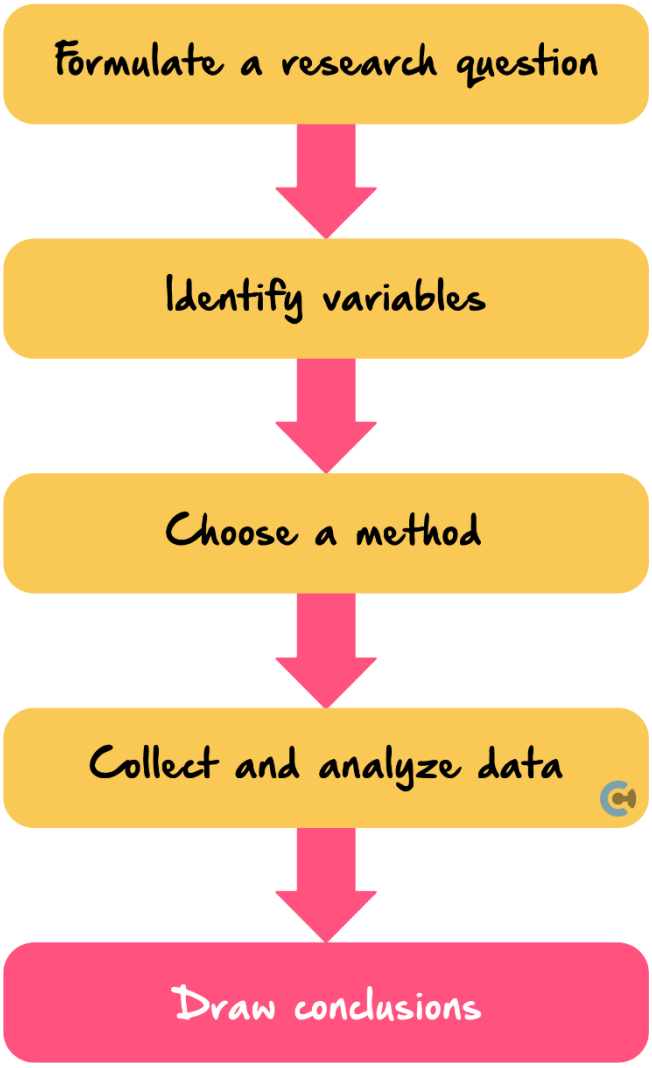
Conventions of science communication: scientific terminology and representations, symbols, formulas, standard abbreviations and units of measurement.

Conventions of scientific poster presentation, including succinct communication of the selected scientific investigation and acknowledgements and references.

The key findings and implications of the selected scientific investigation.

https://www.vcaa.vic.edu.au/Documents/vce/biology/2022BiologySD.docx#page=20

Section A: Designing and Planning Investigations (17 Marks)



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Sub-Section: Research Question and Aim

Research Questions and Aims

- When you are trying to do any practical investigation the first thing to consider is – what do I actually want to know?

- This will generally be decided by your teacher, but if given a choice, you must select a research question.

	Meaning	Example
Specific		
Testable		
Achievable		

- This research question is extremely important as it forms the basis of your experiment and research.

- **Aim:** _____.

Exploration: Can you think of a research question and an aim?

- Research Question:

- Aim:

TIP: Scientifically, you generally have to read the "literature" prior to coming up with a question, but luckily for you, the experiments in VCE Biology aren't that groundbreaking and we can skip this step!

Sub-Section: Variables

Variables

- Variables can essentially be considered any factors that have the potential to be changed during an experiment. Most experiments have the format _____.
- Independent Variable: _____.
- Dependent Variable: _____
- Controlled Variable: _____.

Exploration: Continuing from your research question and aim, come up with IV, DV and some CVs for your experiment.

- IV:
- DV:
- CVs:

Exploration: Why might be it unsuitable to have multiple IVs?

TIP: Once again, specificity is king! Helps the clarity of your experiment greatly.

Question 1 (4 marks)

A student wants to investigate the effect of caffeine on reaction time. They design an experiment where participants drink either caffeinated or decaffeinated coffee before completing a reaction time test.

a. Identify the independent variable (IV) and dependent variable (DV) in this experiment. (2 marks)

_____

_____

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_____

b. Suggest one controlled variable and explain why it is important. (2 marks)

_____

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Sub-Section: Hypothesis

Hypothesis

- A testable statement, that serves as an "educated guess" as to the experiment results.
- If _____, then there will be _____.
- _____.

Misconception

"Hypotheses are just lucky guesses!"

TRUTH: They are based and founded upon previous and existing knowledge.

Exploration: You already know what to do!

- Hypothesis:

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Sub-Section: Methodology

Methodology

- The whole purpose of selecting a certain type of scientific methodology is to determine how to best answer the research question that has been posed.
- Generally, a classroom environment will allow a _____.
- There are many other types of methodologies that are used, but it is likely that you won't have experience with them.
- Controlled experiments _____

_____.

	Methodology
Case Study	An investigation of a particular activity, behaviour, event or problem that contains a real or hypothetical situation and includes the complexities that would be encountered in the real world. Case studies can take various forms: historical, involving the analysis of causes and consequences, and discussion of knowledge learned from the situation; a real situation or a role-play of an imagined situation, where plausible recommendations are to be made; or problem-solving, where developing a new design, methodology or method is required. .
Classification and Identification	Classification is the arrangement of phenomena, objects or events into manageable sets, whereas identification is a process of recognition of phenomena as belonging to particular sets or possibly being part of a new or unique set.
Controlled experiment	An experimental investigation of the relationship between an independent variable and a dependent variable, controlling all other variables.
Correlational study	Planned observation and recording of events and behaviors' that have not been manipulated or controlled to understand the relationships/associations that exist between variables, to identify which factors may be of greater importance and to make predictions.

Fieldwork	Based on inquiry or the investigation of an issue, fieldwork involves observing and interacting with a selected environment beyond the classroom, usually in an attempt to determine a correlation, rather than a causal relationship. It may be conducted through direct qualitative and/or quantitative observations and sampling, participant observation, interviews and questionnaires.
Literature review	Involves the collation and analysis of secondary data related to other people's scientific findings and/or viewpoints in order to answer a question or provide background information to help explain observed events, or as preparation for an investigation to generate primary data.
Modelling	Involves the construction of: a physical model, such as a small- or large-scale representation of an object; a conceptual model, which represents a system involving concepts that help people know, understand or simulate the system; or a mathematical model, which describes a system using mathematical equations that involve relationships between variables and that can be used to make predictions.
Product, process or system development	Design of an artefact, process or system to meet a human need, which may involve technological applications in addition to scientific knowledge and procedures.

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Question 2 (3 marks)

A student conducts an experiment to measure the boiling point of water but consistently records a temperature of 95°C instead of 100°C.

a. Identify whether this is a random or systematic error and justify your answer. (2 marks)

_____

_____

_____

_____

b. Suggest one way to correct this error. (1 mark)

_____

_____

Question 3 (3 marks)

A researcher wants to study the effect of air pollution on plant growth in Melbourne. They are considering two methods:

- Growing plants in a controlled lab environment with different pollution levels.
- Observing plants in various locations around Melbourne with different pollution levels.

a. Which method is a controlled experiment, and which is an observational study? (2 marks)

_____

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_____

b. Which method provides stronger evidence for causation? Explain why. (1 mark)

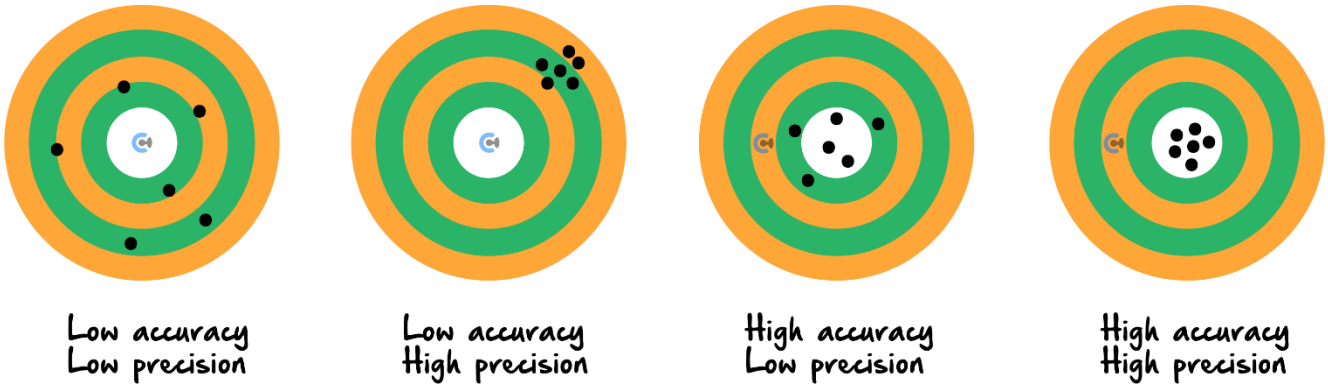
_____

_____

Sub-Section: Investigation Terminology

Key Terms and Characteristics of an Investigation

- When determining the methodology and coming up with a preliminary sequence of steps, it is useful to consider these key terms and characteristics.
- **Repeatable:** _____.
- **Reproducible:** _____.
- **Valid:** _____.
- Replication of your experiment is also extremely important, as it helps you determine whether it is.
- **Precise:** _____.
- **Accurate:** _____.



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Question 4 (3 marks)

A scientist is measuring the mass of a 50.0 g weight using two different scales.

- Scale A gives results of 49.8 g, 49.9 g, and 50.1 g.
- Scale B gives results of 45.2 g, 45.3 g, and 45.2 g.

a. Which scale is more precise? Explain why. (2 marks)

_____

_____

_____

_____

b. Which scale is more accurate? Explain why. (1 mark)

_____

_____

Exploration: For broader science-shaping experiments, why are these principles so significant?

Question 5 (4 marks)

A school is testing whether listening to music while studying improves student test scores. They compare two groups:

- **Group *A*:** Listens to music while studying.
- **Group *B*:** Studies in silence.

a. What is a possible confounding variable in this experiment? (2 marks)

_____

_____

_____

_____

b. How could the researchers modify the study to reduce the effect of confounding variables? (2 marks)

_____

_____

_____

_____

Exploration: The placebo effect

Exploration: Why is replication important in relation to precision and accuracy?

Exploration: Come up with the control and experimental groups for your experiment!

TIP: It is always good to have a clear idea of your experimental groups PRIOR to starting, otherwise you may get confused with the settings applied to each!

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Sub-Section: Types of Errors

Errors

Errors	Meaning
Personal Errors	
Random Error	
Systematic Error	

- These errors should be considered prior to finalising any methodology.

Exploration: Think of some examples of these types of errors that might be present in your experiment!

Sub-Section: Ethics and Safety

Ethical and Safety Guidelines

- As with any experiment, we must ensure that safety and ethical principles are being upheld.
  - Use the bioethics framework to determine whether there are issues or not!
- Safety risks are often judged using a risk assessment form – these can be found online, you just have to be aware of all the materials and actions and what risks they pose, and then collate them as part of your methodology.

Exploration: Why might things such as animal testing be considered unethical?

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Section B: Conducting Practical Investigations

Running the Experiment and Collecting Data

- This is where you collect data from your experiment which will help you draw a conclusion – you have to know what to measure!
  - Primary Data
  - Secondary Data
- Observations are extremely important as well – everything can be used later on when analysing and presenting!

Exploration: Logbooks are incredibly important, what are some of the things that you may want to note down?

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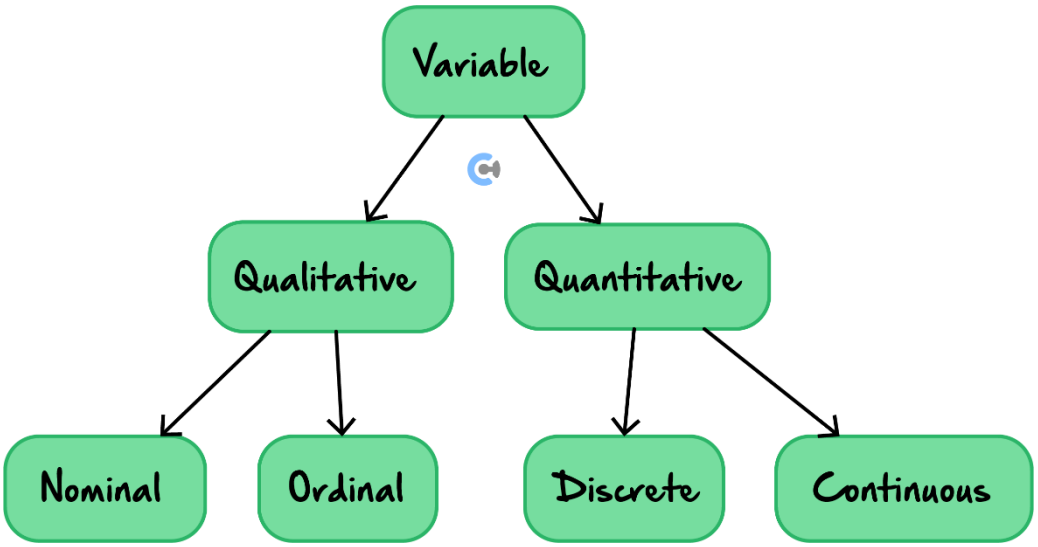
Section C: Analysing and Presenting Results (5 Marks)

Sub-Section: Types of Data & Principles of Graphing

Transforming Data

- Before we can decide how to best present or transform our data, we must know the different types of data of variables we can collect.

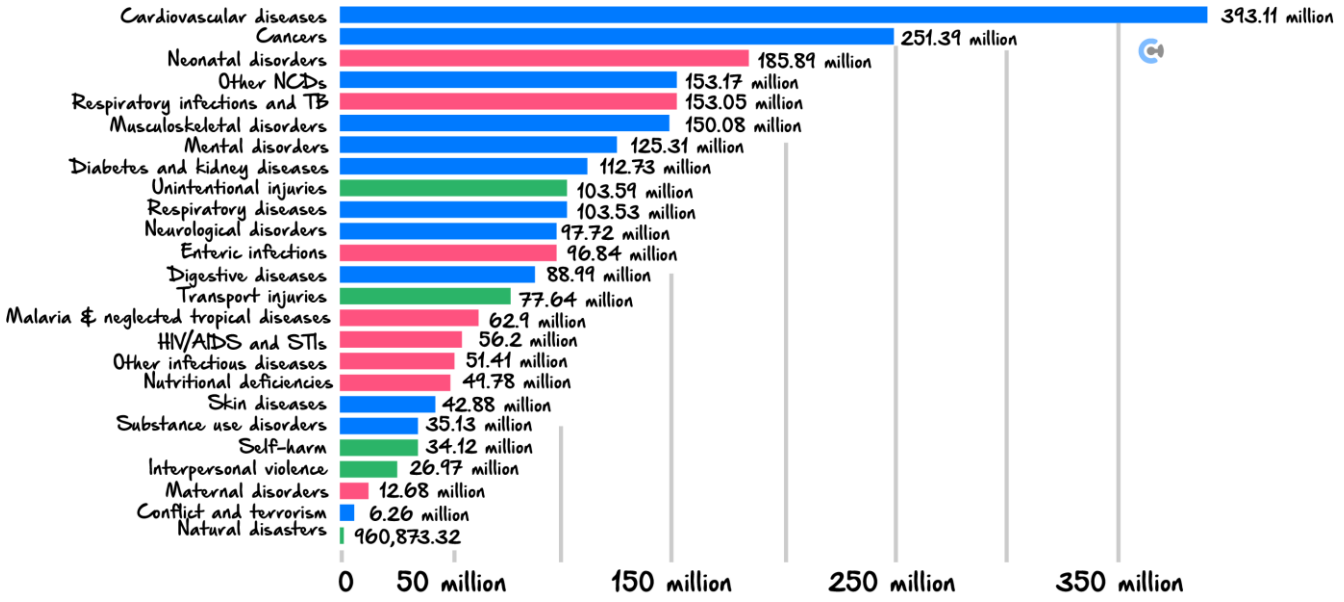


- Nominal : _____.
- Ordinal : _____.
- Discrete : _____.
- Continuous : _____.

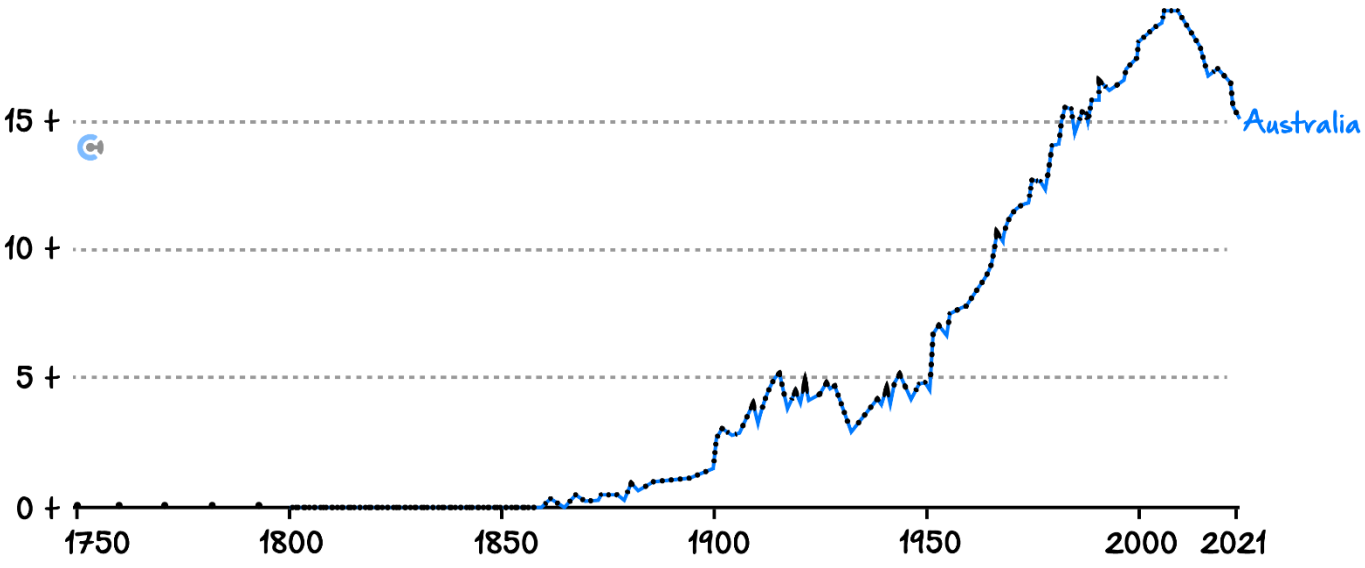
Exploration: How would you graph or represent each of these variables if used in an experiment?

- Nominal: _____.
- Ordinal: _____.
- Discrete: _____.
- Continuous: _____.

- Burden of disease by cause, World 2019



- Per capita CO_2 emissions



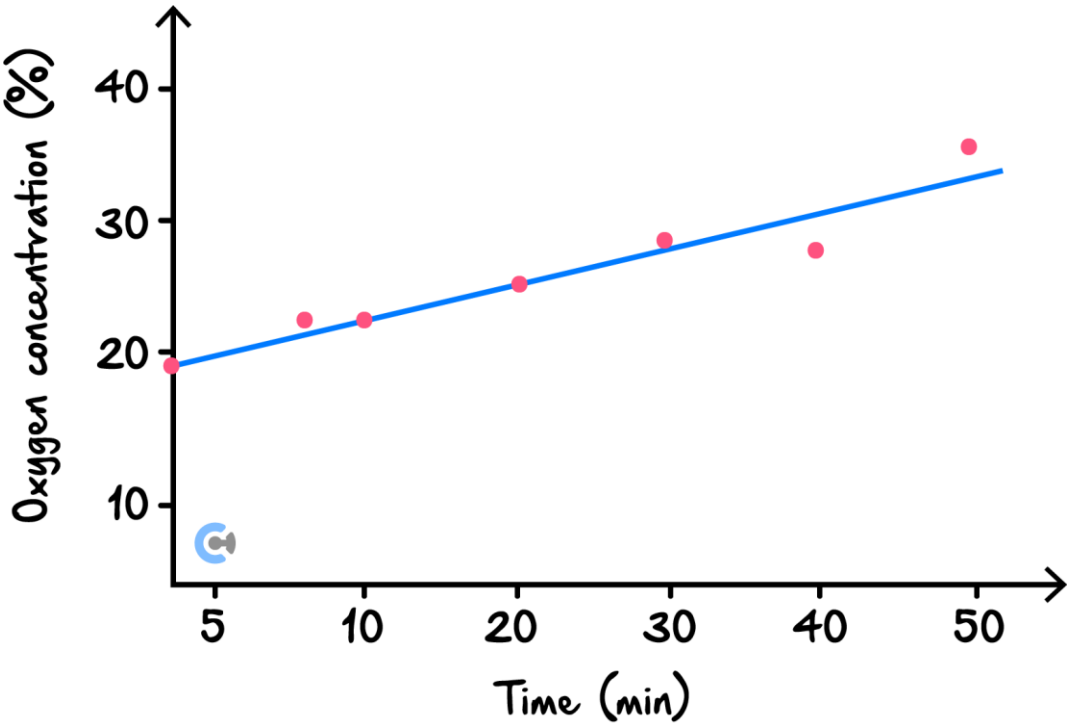
Exploration: Look at the graphs, state what are their variables and justify their graphing choice!

- Graph 1 : _____.
- Graph 2 : _____.

Sub-Section: Drawing Graphs

Principles of Graphing

- In your experiment or the final exam, you will inevitably have to draw a graph yourself, most likely it will be a scatterplot, where all the points can be plotted with 2 continuous variables.
  - Include a trendline in this case, as it allows better analysis of trends.



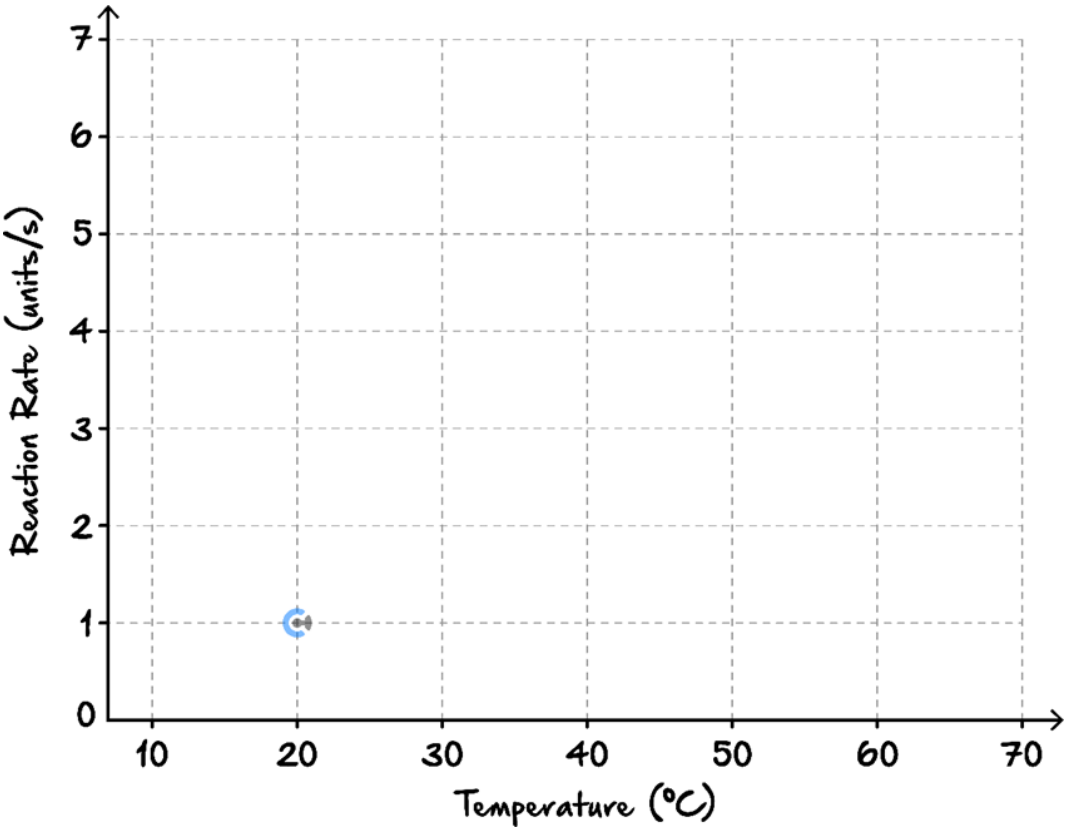
- Everything should be clear and easy to view.
- Choose an appropriate scale.
- No grid lines or background colours, unless otherwise determined by your teacher.
- MUST have a title.
- Axis labels in sentence case.
- Axis labels should always have the units in brackets.
- Calculation methods should be clear.
- Should also include a 1-2 sentence summary of findings or trends.

Question 6 (5 marks)

A group of students conducted an experiment to investigate how temperature affects enzyme activity. They measured the rate of reaction (in arbitrary units) at different temperatures and recorded the following data:

Temperature (°C)	Reaction Rate (units/*s*)
10°C	1.2
20°C	2.5
30°C	4.8
40°C	6.1
50°C	5.2
60°C	2.7
70°C	0.5

a. On graph paper, draw a line graph to represent this data. (3 marks)



b. Based on your graph, describe the trend in enzyme activity as temperature increases. (2 marks)

_____

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Sub-Section: Analysis of Data and Method

Analyse Data and Method

- The visualisation of your results means that you can easily identify any trends and suggest whether your hypothesis was supported or not.
- Not only do you have to complete that, but you also have to ensure that your method is valid and reliable.
- Describe results – Analyse results for the purpose of your hypothesis.
- Method Analysis – What could this include?
- Data Analysis – What could this include?

Conclusions

- Once all this has been achieved, you have to draw evidence-based conclusions – they must be backed up properly.
  - It is okay to not have a conclusion – say that the experiment was flawed and nothing should be concluded!

Exploration: Correlation does not equal causation! What does this mean?

Exploration: Extrapolation!

Presenting Results – Practical Investigation Poster

- Ideally, your school should follow the VCAA requirements listed in the study design, but if not, let me know and I'll give you additional advice based on their rubric!

Title A - Student name		
Introduction Methodology and methods Results	Communication statement reporting the key finding of the investigation as a one-sentence summary.	Discussion. Conclusion.
References and acknowledgements		

- This is the general format – it's designed to be a quick punchy summary of your investigation and it's important to keep things concise.

Section	Description	Length
Title	Should be posed as a question – be specific.	1 question.
Abstract	Optional – short overview of the entire question.	2-3 sentences.
Introduction	➢ Background Information: ○ Context, scientific information, explanations, why is this research important. ○ Gaps in knowledge relating to experiments. Aim, Variables, Hypothesis How could this influence knowledge in general?	A few paragraphs.
Method	Steps. Diagrams, equipment. Observations if relevant.	
Results	Transformed Data – not altered, 2-3 sentences of description.	Depends on how many results presenting.
Discussion	➢ Data analysis: ○ Describe the patterns and figures from your results. ○ Hypothesis. ○ Findings support or differ from introductional research. ○ Make a statement on the validity. ○ Error analysis. ○ Limitations. ○ Improvements. ○ Specific factors.	3-4 paragraphs.

Conclusion	➢ Summarise your study: • Hypothesis statement and justification. • Summary of findings and improvements. • Future impacts.	2-3 sentences.
Acknowledgements	"All praise to Aaliyan, my amazing biology tutor."	Not included in the word count.
References	References are typically for the introduction background - just follow your teacher's guidelines.	Not included in the word count but should have 5.

Planning and designing	Conducting	Analysing and presenting
What is my research question and aim?	How do I collect data?	What is the best way to present my raw data?
What are my IV, DV, and controlled variables?	How do I record potential errors and observations?	What errors might there be with my methods and data that could invalidate my results?
What is my hypothesis?	How do I work best with my team?	What conclusions can I draw from these results?
What methodology is appropriate?		How should I communicate my findings?
How do I design a reproducible, repeatable, and valid method that is both accurate and precise?		
What ethical and safety guidelines should I follow?		

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