Group 4 Sciences Internal Assessment and Individual Investigation

Student Guide

Lincoln School IB

Contents

Introduction

This booklet is aimed at helping you to build the necessary skills needed for the Internal Assessment Individual Investigation that will be carried out during the course. Here you will find details of how to succeed in each aspect of the Individual Investigation, investigation timelines, grading criteria, common investigation techniques, details on statistical methods and Internal Assessment policies.

The Individual Investigation is a significant piece of work, requiring approximately 10 hours of lab work and the application of many different skills. During your Group 4 lessons your teacher will have introduced those skills to you. The final write-up should be 6-12 pages long (if you exceed 12 pages you will be penalised). The Individual Investigation contributes 20% of the final assessment.

The Individual Investigation is not the only requirement for successful completion of the course. Each of you will also complete the Group 4 Project and a number of hours of logged lab time (40 hours for standard level and 60 for higher level).

The nature of the task is chosen by you. Some of the possible tasks include:

- a laboratory investigation (most common format)
- using a spreadsheet for analysis and modelling
- extracting data from a database and analysing it graphically
- producing a hybrid of spreadsheet/database work with a traditional hands-on investigation
- using a simulation provided it is interactive and open-ended

All submitted work must be word processed and supported by relevant graphical and analytical programs as appropriate.

Timeline for completion

Section	Sub-section	Time period	Additional Information
Initiation	Introduction	1 Lesson - 29th April	
	Derivation of Research Question	1 lesson – 6th May	You are expected to come with ideas and inspiration. This is your submitted work.
Research	Begin the discovery of sources and research	Immediately after the research question is set	Once you have the research question in outline, you can begin researching the topic area, collecting sources of information and getting an idea of the method, timeframe and potential results.
	Derivation of methodology	Second week of May	Write your method
	Preliminary data collection	Third week of May	Attempt a trail run of your method to see if the process works and you get meaningful data. These results should be included in your report as evidence of planning
Execution	Data collection	End of May into June	Collect your data in whatever format you have chosen. Remember to make qualitative as well as quantitative observations
	Data analysis	Over Summer	Calculation of uncertainties, standard deviation, graphing and statistical analysis goes here
Draft	Writing of the draft	Over Summer	
	Hand-in and mentoring the draft	September/ October	Your teacher will help you make improvements to the report. They will not be able to give specific points of improvements, only identify potential areas of weakness
Final report	Deadline	November	

Individual investigation criteria explained

The internally assessed component of the course is divided into five sections.

- Personal engagement
- Exploration
- Analysis
- Evaluation
- Communication

Personal engagement	Exploration	Analysis	Evaluation	Communication	Total
2 (8%)	6 (25%)	6 (25%)	6 (25%)	4 (17%)	24 (100%)

Each section aims to assess a different aspect of the student's research abilities. The sections are differently weighted to emphasize the relative contribution of each aspect to the overall quality of the investigation. As the investigations, and therefore the approaches to the investigation, will be specific to each student, the marking criteria are not designed to be a tick-chart markscheme and each section is meant to be seen within the context of the whole. As such, a certain degree of interpretation is inevitable. The following tips are designed to help focus on the intention of each section, rather than be seen as a definitive approach.

Personal engagement

Mark	Descriptor
0	The student's report does not reach a standard described by the descriptors below.
1	The evidence of personal engagement with the exploration is limited with little independent thinking, initiative or insight. The justification given for choosing the research question and/or the topic under investigation does not demonstrate personal significance, interest or curiosity. There is little evidence of personal input and initiative in the designing, implementation or presentation of the investigation.
2	The evidence of personal engagement with the exploration is clear with significant independent thinking, initiative or insight. The justification given for choosing the research question and/or the topic under investigation demonstrates personal significance, interest or curiosity. There is evidence of personal input and initiative in the designing, implementation or presentation of the investigation.

Personal engagement: key guidance

The emphasis within this section is on individuality and creativity within the investigation. The question to ask is, has the chosen research question been devised as a result of the personal experience or innovative thinking? The question could be a result of observations made in your own environment or ideas that you have had as the result of learning, reading or experimenting in class. The investigation does not have to be ground-breaking research, but there should be an indication that independent thought has been put into the choice of topic, the method of inquiry and the presentation of the findings. The topic chosen should also be of suitable complexity. If the research question is very basic or the answer self-evident then there is little opportunity to gain full marks for exploration and analysis as you will not have the opportunity to demonstrate your skills.

Exploration

Mark	Descriptor
0	The student's report does not reach a standard described by the descriptors below.
1–2	The topic of the investigation is identified and a research question of some relevance is stated but it is not focused. The background information provided for the investigation is superficial or of limited relevance and does not aid the understanding of the context of the investigation. The methodology of the investigation is only appropriate to address the research question to a very limited extent since it takes into consideration few of the significant factors that may influence the relevance, reliability and sufficiency of the collected data. The report shows evidence of limited awareness of the significant safety, ethical or environmental issues that are relevant to the methodology of the investigation*.
3–4	The topic of the investigation is identified and a relevant but not fully focused research question is described. The background information provided for the investigation is mainly appropriate and relevant and aids the understanding of the context of the investigation. The methodology of the investigation is mainly appropriate to address the research question but has limitations since it takes into consideration only some of the significant factors that may influence the relevance, reliability and sufficiency of the collected data. The report shows evidence of some awareness of the significant safety, ethical or environmental issues that are relevant to the methodology of the investigation*.

5–6	The topic of the investigation is identified and a relevant and fully focused research question is clearly described. The background information provided for the investigation is entirely appropriate and relevant and enhances the understanding of the context of the investigation. The methodology of the investigation is highly appropriate to address the research question because it takes into consideration all, or nearly all, of the significant factors that may influence the relevance, reliability and sufficiency of the collected data. The report shows evidence of full awareness of the significant safety, ethical or environmental issues that are relevant to the methodology of the investigation*.

Exploration: key guidance

The issue here is the overall methodology. You need to take your individual ideas and translate them into a workable method. You must also demonstrate the thinking behind your ideas using your subject knowledge. The information given must be targeted at the problem, and highly focussed on the research question - rather than being a general account of the topic matter, in order to demonstrate focus on the issues at hand. You will be expected to include some background information on the area of study, but you must judge carefully which materials pertain directly to the research question and only include those.

What needs to be seen is a precise line of investigation that can be assessed using scientific protocols. It is then expected that you give the necessary details of the method in terms of variables, controls and the nature of the data that is to be generated. This data must be of sufficient quantity and treatable in an appropriate manner, so that it can generate a conclusion, in order to fulfil the criteria of analysis and evaluation. If the method devised does not lead to sufficient and appropriate data, this will lead to you being penalized in subsequent sections where this becomes the crux of the assessment.

Health and safety is a key consideration in experimental work and forms part of a good method. If you are working with animals or tissue, it is reasonable to expect there to be evidence that the guidelines for the use of animals in IB World Schools have been read and adhered to. The use of human subjects in experiments is also covered by this policy. The IB animal experimentation policy is far reaching and will ethically limit what you can achieve. If you are working with chemicals, some explanation of safe handling and disposal would be expected. Full awareness is when all potential hazards have been identified, with a brief outline given as to how they will be addressed. It is only acceptable for there to be no evidence of a risk assessment if the investigation is evidently risk-free—such as in investigations where a database or simulation has been used to generate the data.

Analysis

Mark	Descriptor
0	The student's report does not reach a standard described by the descriptors below.
1–2	The report includes insufficient relevant raw data to support a valid conclusion to the research question. Some basic data processing is carried out but is either too inaccurate or too insufficient to lead to a valid conclusion. The report shows evidence of little consideration of the impact of measurement uncertainty on the analysis. The processed data is incorrectly or insufficiently interpreted so that the conclusion is invalid or very incomplete.
3–4	The report includes relevant but incomplete quantitative and qualitative raw data that could support a simple or partially valid conclusion to the research question. Appropriate and sufficient data processing is carried out that could lead to a broadly valid conclusion but there are significant inaccuracies and inconsistencies in the processing. The report shows evidence of some consideration of the impact of measurement uncertainty on the analysis. The processed data is interpreted so that a broadly valid but incomplete or limited conclusion to the research question can be deduced.
5–6	The report includes sufficient relevant quantitative and qualitative raw data that could support a detailed and valid conclusion to the research question. Appropriate and sufficient data processing is carried out with the accuracy required to enable a conclusion to the research question to be drawn that is fully consistent with the experimental data. The report shows evidence of full and appropriate consideration of the impact of measurement uncertainty on the analysis. The processed data is correctly interpreted so that a completely valid and detailed conclusion to the research question can be deduced.

<u>Analysis: key guidance</u>

At the root of this section is the data generated and how it is processed. If there is insufficient data then any treatment will be superficial. It is hoped that you would recognize such a lack and revisit the method before the analysis is arrived at. Alternatively, the use of databases or simulations to provide sufficient material for analysis could help in such situations.

Any treatment of the data must be appropriate to the focus of the investigation in an attempt to answer the research question. The conclusions drawn must be based on the evidence obtained from the data rather than on assumptions. Given the scope of the internal assessment and the time allocated, it is more than likely that variability in the data will lead to a tentative conclusion. This should be recognized and the extent of the variability considered. The variability should be demonstrated and explained and its impact on the conclusion fully acknowledged. It is important to note that, in this criterion, the word "conclusion" refers to a deduction based on direct interpretation of the data, which is based on asking questions such as: What does the graph show? Does any statistical test used support the conclusion?

Your conclusion will need to be clear, simple and precise; it needs to relate directly to your hypothesis (agreeing or disagreeing).

The following is an example of a poor conclusion: *there is a difference in the number of attacks by the holly leaf miner and the height in the hedge*. A good example is: *there is a significantly greater number of attacks by the holly leaf miner above a height of 1000mm in the holly hedge compare to below 1000mm*

Evaluation

Mark	Descriptor
0	The student's report does not reach a standard described by the descriptors below.
1–2	A conclusion is outlined which is not relevant to the research question or is not supported by the data presented. The conclusion makes superficial comparison to the accepted scientific context. Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are outlined but are restricted to an account of the practical or procedural issues faced. The student has outlined very few realistic and relevant suggestions for the improvement and extension of the investigation.
3–4	A conclusion is described which is relevant to the research question and supported by the data presented. A conclusion is described which makes some relevant comparison to the accepted scientific context. Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are described and provide evidence of some awareness of the methodological issues* involved in establishing the conclusion. The student has described some realistic and relevant suggestions for the improvement and extension of the investigation.
5–6	A detailed conclusion is described and justified which is entirely relevant to the research question and fully supported by the data presented. A conclusion is correctly described and justified through relevant comparison to the accepted scientific context. Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are discussed and provide evidence of a clear understanding of the methodological issues* involved in establishing the conclusion. The student has discussed realistic and relevant suggestions for the improvement and extension of the investigation.

Evaluation: key guidance

Although it may appear that you are being asked to repeat the analysis of the data and the drawing of a conclusion again in the evaluation, the focus is different. Once again the data and conclusion come under scrutiny but, in the evaluation, the conclusion is placed into the context of the research question.

So, in the analysis, it may be concluded that there is a positive correlation between x and y; in the evaluation, you are expected to put this conclusion into the context of the original aim. In other words, does the conclusion support your original thinking in the topic? If not, a consideration of why it does not will lead into an evaluation of the limitations of the method and suggestions as to how the method and approach could be adjusted to generate data that could help draw a firmer conclusion.

Variability of the data may well be mentioned again in the evaluation as this provides evidence for the reliability of the conclusion. This will also lead into an assessment of the limitations of the method. It is the focus on the limitations that is at issue in the evaluation, rather than a reiteration that there is variability. Evaluation of your results – just think at the following: how reliable are your results? Do the repeats support each other? Are any uncertainties large enough to have a significant effect? How large is the standard deviation? Does the graph match the prediction? Why did you use that particular statistical test? You should aim to write a comment on as many as these points as you can.

Comment on both the strengths and weaknesses of your method - how do you feel it was successful, and in what way did it fall short of satisfactory? You will also want to mention a potential extension to your work, in other words – how would you follow on from this experiment?

You are required to comment on the extent to which you feel the uncertainty affected the results, the validity of your final conclusions (eg. The average height of bean seeds exposed to more CO2 was 10cm more over the experiment period, than those bean seeds not exposed to CO2. As the uncertainty was only +- 1cm I am confident that the degree of uncertainty does not compromise the validity of my interpretation).

If you can, comment on how your results compares with the accepted theory of scientific literature. Make sure you do this with the understanding of what your results indicate, including conflicting interpretations of your data.

Your improvements could be something that you actually did during the investigation regardless of your planning and you have to give a reason for the change. They also could be hypothetical, and express what you would have done differently in the light of experience. It is best to be systematic here, discuss the problem, state the possible effect on your results, and then state a realistic improvement (eg. I didn't have enough trials, therefore my results may be unreliable and I am not confident that they could be repeated under the same conditions, and I could avoid this by extending the experiment to include 5 trials instead of one).. The improvement must not be superficial, ie. We need more time, the instructions were not clear, but you can suggest the use of better equipment as you may not be responsible for the material that it is provided to you.

Communication

Mark	Descriptor
0	The student's report does not reach a standard described by the descriptors below.

1–2	The presentation of the investigation is unclear, making it difficult to understand the focus, process and outcomes. The report is not well structured and is unclear: the necessary information on focus, process and outcomes is missing or is presented in an incoherent or disorganized way. The understanding of the focus, process and outcomes of the investigation is obscured by the presence of inappropriate or irrelevant information. There are many errors in the use of subject-specific terminology and conventions*.
3–4	The presentation of the investigation is clear. Any errors do not hamper understanding of the focus, process and outcomes. The report is well structured and clear: the necessary information on focus, process and outcomes is present and presented in a coherent way. The report is relevant and concise thereby facilitating a ready understanding of the focus, process and outcomes of the investigation. The use of subject-specific terminology and conventions is appropriate and correct. Any errors do not hamper understanding.

Communication: key guidance

The marking points for communication take the entire write-up into consideration. If a report is clearly written and logically presented there should be no need for the marker to re-read it. The information and explanations should be targeted at the question in hand rather than being a general exposition of the subject area; in other words, the report should be focused.

The vocabulary should be subject-specific and of a quality appropriate to Diploma Programme level. The subject-specific conventions that can be expected are the correct formats for graph and tables and cell headings, correct use of units and the recording of errors. This is not to say that the presentation needs to be faultless to gain full marks. Minor errors are acceptable as long as they do not have a significant bearing on understanding or the interpretation of the results.

Personal Engagement __/2	
☐	The evidence of personal engagement with the exploration is clear with significant independent thinking, initiative or insight.
☐	The justification given for choosing the research question and/or the topic under investigation demonstrates personal significance, interest or curiosity.
☐	There is evidence of personal input and initiative in the designing, implementation or presentation of the investigation.
Exploration __/6	**Research question, Background, Variables, Methods**
☐	The topic of the investigation is identified and a relevant and fully focused research question is clearly described.
☐	Background information is entirely appropriate and relevant, and enhances the understanding of the context of the investigation. Includes binomial name of species studied (if applicable) and research of possible outcome of experiment (include citation and bibliography)
☐	Independent and dependent variables are specifically identified and at least 5 levels/conditions of the independent variable are tested
☐	All relevant controlled variables are identified
☐	Specific methods to control these variables are given in table form: controlled variables/why controlled? /How controlled?
☐	Appropriate method for collecting data is carried out
☐	Standard methods are referenced that include large enough range, sufficient data in that range, sufficient repeats, and measurements allowing for sufficient precision
☐	Reference is made to the outcome expected for each condition of the independent variable
☐	Shows awareness of safety, ethical or environmental issues relevant to the investigation (ex: research into tolerance limits of animal or consent form for Human subjects)
☐	Procedure is detailed enough for a peer to follow and produce the same results
Analysis __/6	**Raw data and Processed Data, Graphs, Statistical analysis**
☐	Relevant and sufficient quantitative data is collected
☐	Relevant and sufficient qualitative data is collected
☐	Quantitative raw data is processed correctly
☐	Quantitative data is displayed clearly and easy to understand in a table (with ruled rows and columns) with appropriate significant digits
☐	Table has a meaningful title and headings for rows and column, units are included and a caption is present that describes the contents of table(s)
☐	The report shows evidence of full and appropriate consideration of the impact of measurement uncertainty on the analysis. Uncertainties or problems are noted.
☐	Suitable statistics are calculated and sample calculations are shown for every type of calculation carried out (i.e. averages , standard deviations, t- test)
☐	If 2 sets of data are compared, statistical analysis is included (i.e. correlations, t-test)
☐	The processed data is correctly interpreted so that a completely valid and detailed conclusion to the research question can be deduced.
Evaluation __/6	**Conclusion and Evaluation**
☐	A detailed conclusion is given which is relevant to the research question and fully supported by the data presented.
☐	Conclusion is justified through comparison to accepted scientific context. (Experimental values are compared to published values and citation is included)
☐	A discussion of strengths and weaknesses of the investigation, such as limitations of the data and sources of error, is made.
☐	Discusses the control of variables, limitations on interpretation of the data, the design of the investigation, and the quality (precision, amount , range) of the data
☐	Discusses realistic and relevant suggestions for the improvement and extension of the investigation.
Communication __/4	
☐	The presentation of the investigation is clear. Any errors do not hamper understanding of the focus, process and outcomes.
☐	The report is well structured and clear: the necessary information on focus, process and outcomes is present and presented in a coherent way.
☐	The report is relevant and concise thereby facilitating a ready understanding of the focus, process and outcomes of the investigation.
☐	The use of subject-specific terminology and conventions is appropriate and correct. Any errors do not hamper understanding

Compiled by S. Nelson, 2014, based on documents by G. Wacker, S. Bruce and L. Young.

How to write the Investigation

Section	Content	Explanation/Notes
Title	The research question as a title	
Introduction	Research question (RQ) Objective/rationale Hypothesis	The precise question that will be addressed The relevance and context of the RQ Prediction of the result backed by research
Apparatus	Full list of apparatus, reagents	Including sizes, uncertainties, quantities
Variables	Independent Dependent Controlled Measured (Confounding) variables	Manipulated by experimenter Varies as a consequence Kept constant by experimenter Measured but not controlled Uncontrollable, may affect result
Procedure	Exact methodology	Full, repeatable procedure
Raw data	Quantitative data Qualitative data	With units, uncertainties, tabulated Observations that are not quantifiable
Data processing	Mathematical (statistical) processing and representation	Tables, graphs, nomograms and so on See TSM material on graphical representation
Evaluation	Conclusion based on data Comparison to research Identification of weaknesses Realistic improvements	Use of raw and processed data Procedural weaknesses
Ethical, safety and environmental considerations	Reagents Apparatus Use of human subjects Use of animals	Personal and disposal safety issues Informed consent Compliance with IB guidelines
Appendix	Photographs Acknowledgments Raw data	Can be appendicized or in the body of the report

Title

The title of your Investigation will be very similar to your Research question, however it may be condensed into a shorter structure.

Research Question

This section of the investigation is a number of sentences that discusses the objective or purpose of your investigation clearly and specifically. Once you have decided on your research topic, it is important to identify a focussed question. Questions are good because they:

- give guidance and focus to both your research and your product
- help you to actually address an issue rather than just talking round a topic
- require you to provide an answer, and to justify it with reasoned arguments – they make it easier to say something original and interesting

Your experiment will be designed around the effect of changing one variable and measuring the effect of the change on another variable.

Hypothesis

A hypothesis is like a prediction. It will often take the form of a proposed relationship between two or more variables that can be tested by experiment: "If X is done, then Y will occur."

> "As the surface area increases, the temperature loss will increase"
> "The rate of the reaction should increase if the concentration of enzyme is increased"

You must also provide an explanation for your hypothesis. This should be a brief discussion about the theory or "why" behind your hypothesis and prediction. For example, why should increasing enzyme concentration increase the rate? Why does the temperature loss increase when the surface area increases?

Include any relevant science, such as balanced chemical equations, if necessary to explain your hypothesis.

Variables

Variables are those factors that might influence the outcome of the experiment. You should identify and list all reasonable variables, and briefly state why each one is relevant.

- Independent Variable - The independent variable is the one condition that you change in an experiment. You should also give the units as appropriate.
  Example: In an experiment measuring the effect of temperature on solubility, the independent variable is temperature.

- Dependent Variable - The dependent variable is the variable that you measure or observe. The dependent variable gets its name because it is the factor that is dependent on the independent variable. Once again, give the units as appropriate.
  Example: In the experiment measuring the effect of temperature on solubility, solubility would be the dependent variable.

- Controlled Variable - A controlled variable or constant variable is a variable that does not change during an experiment. There will be many control variables and they will have significant or little impact on the investigation. You should state each control, how you will control it and the level of impact. You should also reference those variables that you cannot control, such as atmospheric pressure.
  Example: In the experiment measuring the effect of temperature on solubility, controlled variable could include the source of water used in the experiment, the size and type of containers used to mix chemicals, and the amount of mixing time allowed for each solution.

Apparatus and Materials

Make a diagram or sketch of your experimental setup, and label the items. Photographs are a good alternative as well. Then list the materials you used. Be as specific as possible, for example a "50 cm^3 beaker" instead of a "beaker".

Method/Procedure

Write the method (procedure) that you are going to use (or that you did use) in the experiment. This should be in the form of a bulleted list of step-by-step directions. Provide enough detail so that another person could repeat your work by reading your report. However don't be repetitive! If you are doing several experiments using basically the same procedure outline a basic procedure then simply state what changed.

If you do something in your procedure to minimize an anticipated error, mention this as well. (Example: "Carefully rinse the measuring cylinder before filling it so water inside doesn't affect the concentration of the solution).

In your method, clearly state how you will collect data. What measuring device will you use, what data will you record, and when. Describe the qualitative observations will you look for (such as a color change) and what will you do when you see this happen.

The procedure must allow collection of sufficient relevant data. This means that you should consider doing three or more trials where appropriate. This is especially true when doing things like titrations.

Refer to the variables that need to be controlled. State clearly how each of these variables will be controlled. (For example, if the temperature must remain constant, figure out how you will do this and state it. Perhaps you might use a water bath that is maintained at a certain temperature. Or perhaps the atmospheric pressure must remain constant. In this case, you might read the laboratory barometer before and after the experiment, or do the experiments all on the same day so atmospheric pressure doesn't vary.

List any safety precautions that must be taken or were taken during the lab. Examples:

- “Wear safety goggles throughout the experiment”
- “Be cautious in using strong acids/bases. Rinse off spills with water immediately.”
- “Do not handle microbial samples without gloves and always within a ventilated room”
- “Allow the crucible/test tube to cool after heating. ”
- “Avoid breathing vapors of the hydrocarbon liquids.”

Data Collection

Data comes in two forms: raw data and organised data. If your raw data is extensive, it is usually placed in an appendix not in the results section. Raw data should still be clear.

Raw data is collected as you go, it doesn’t have to make sense instantaneously, but will need to be organised in a table. You will have to decide if your raw data are already organised or might need sorting. This is an example of organised data:

Leaf length / mm ±0.5	Number of leaves
90 – 94	2
95 – 99	3
100 – 104	3
105 – 109	5
110 – 114	4
115 – 119	3
120 – 124	3
125 – 129	1

Each individual item in a table is called a VALUE. There are rules to follow when putting data on a table:

- Use the correct software to draw tables
- Never split table from one page to the next
- Always centre the column of data and align decimal points
- Never put more than one value on the same row
- Table are usually arranged vertically
- The order of the columns must follow a logical sequence: independent variable first, dependent next
- Precise headings
- The columns headings must be the same as the graphs headings on the axes
- Always include uncertainties
- Use SI units in the headings not near the values
- Write an informative title

Informative title

Table 1. Results of the effect of changing temperature on the rate of water uptake in a cut shoot of ivy

Title of each variable

Units of measurements and uncertainty

Temperature / ^{0}C ±0.5	Time taken to travel 10cm / s ±1s
15	80
25	60
35	30
45	10

Data centred

Independent variable

Dependent variable in succeeding column

Anomalous results – these are usually disregarded, but you must be sure that it is a *real* anomalous result. In order to do that you need to calculate the mean and the standard deviation (see relevant section in this booklet) and see if the value lies within certain boundaries. If it does, then you would have been wrong in disregard it. Double check your calculations, in case there is a mathematical error and check that you have plotted them correctly in your graph first. To highlight the anomalous result in your table you need to place a star * next to the corresponding value. However, it is not possible to calculate the standard deviation with a small sample. If you are only collecting data regarding a short experiment then highlight as anomalous any extraordinary value. Remember that biological data is highly variable and it is important not to accuse a certain result as being anomalous unless the sample is big enough to allow you to reach such conclusion.

Processing data – Averages

There are three ways to measure the average: mean, median and mode. The mean is commonly known as the 'mathematical average' calculated by dividing the sum of all samples by the sample size. The median is the middle number of results, when arranged in rank order. The mode is the measurement that occurs within the greatest number of times.

Processing data – Standard deviation and statistical analysis

Calculating the mean is not enough to show good data processing within your analysis element. You need to include the standard deviation as a tool to show the spread of values around a mean (see Standard Deviation section). Good practice of including some statistical analysis in your table shows greater understanding of the experiment and its validity (See statistics section).

Graphs

Graphs provide a visual relationship between the values you have gathered during the practical activity.There are many types of graph, but which one used depends on the type of data you collected:

Line graphs are used when you have carried out an experiment with dependent and independent variables

Scatter graphs are useful to see the correlation between two sets of data, neither of which has been manipulated

Bar graphs and histograms are similar in appearance, but distinct in use: in a bar graph there is no relationship between the bars (discreet data) and a space should be left; in a histogram each bar relates to the next and no space is left between them (continuous data).

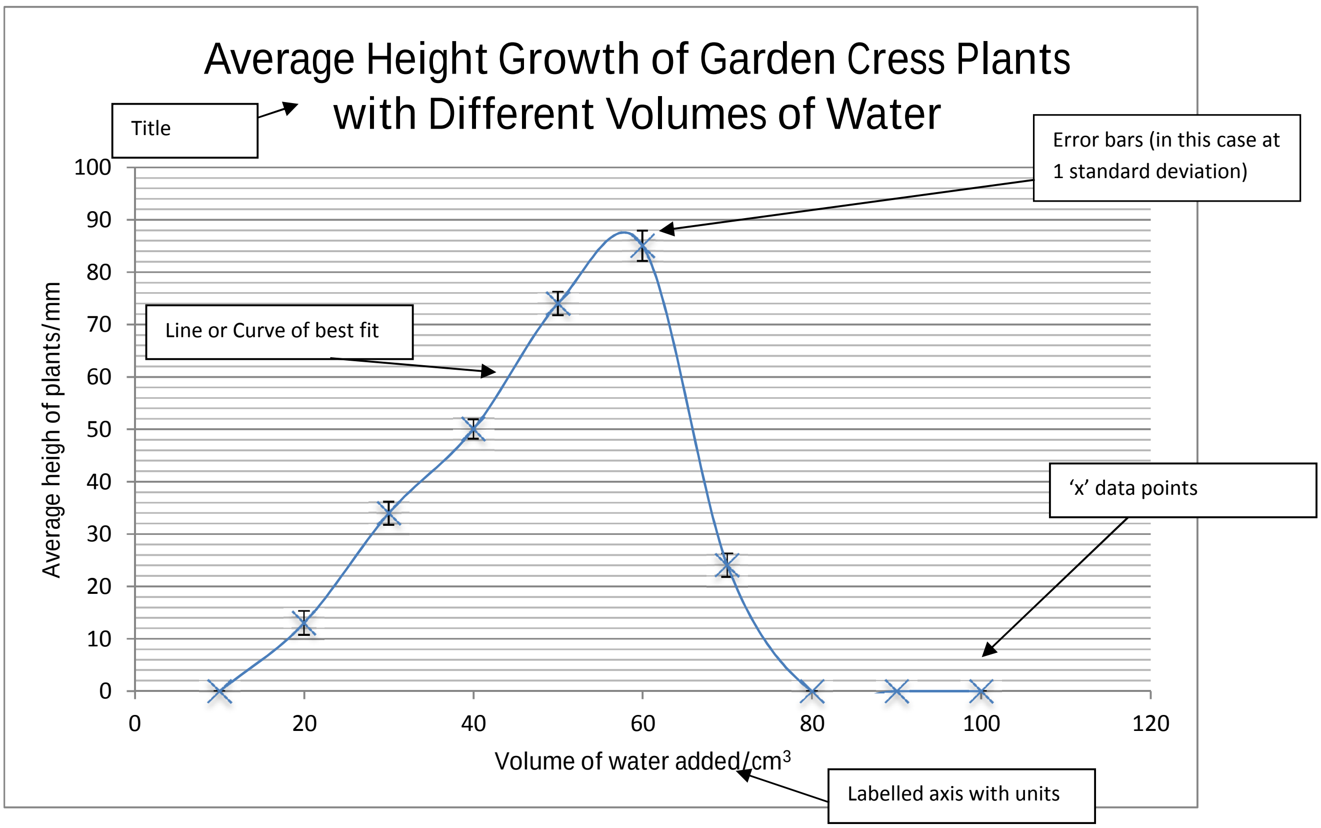
Pie charts show proportions

Kite diagrams show distribution within an area and are often used in ecological studies.

General rules for graphs

- When using Excel change the square plots to 'x' plots
- Save the graph on a separate page so it is larger
- The dependent variable goes on the Y axis
- The independent variable is usually on the X axis
- The scale does not have to start at zero and scale divisions should be simple
- Label the axis and don't forget the units and uncertainties
- Construct an informative title (A graph to show…

Example: Graph showing the average height growth of garden cress plants at different volumes of water



Try to include major and minor gridlines, be careful when selecting either a straight line or a curve of best fit.

Conclusion and Discussion

The conclusion is a few paragraphs in which you draw conclusions from your results, whether your conclusions support your hypothesis and places your results into a scientific context. Your conclusion should be clearly related to the research question and the purpose of the experiment. You must also provide an explanation as to how you came to this conclusion from your results. If a numerical value or result is the object of the lab, you must compare it with the literature values. How does the result match the expected outcome in comparison to other published work? If possible calculate a percent error (see the error analysis section).

Evaluation

The evaluation is a large part of your Individual Investigation. It can be roughly divided into three parts - Strengths, Limitations and Improvements. Whist the strengths is important it will also be the shortest section. Briefly outline the good aspects of the investigation. You may comment here on the strengths of your method, what merits do you feel it had. Alongside this, you can mention where you think it fell short.

The limitations can further break down into data and procedural limitations.

Limitations to Conclusions require considering how large are the errors or uncertainties in your results and confidence in the results. Are the results fairly conclusive, or are other interpretations/results possible?

Limitations of the Experimental Procedure identify and discuss significant errors and limitations that could have affected the outcome of your experiment. Were there important variables that were not controlled? Were there flaws in the procedure you chose which could affect the results? Are measurements and observations reliable? Is precision unknown because of lack of repeated trials?

Your emphasis in this section should be on systematic errors, not the random errors that always occur in reading instruments and taking measurements (although you should mention these where appropriate). You must identify the source of error and if possible, state how it probably affected your results.

Finally you should suggest improvements or fixes for the weaknesses you identified in the previous section. These suggestions should be realistic, keeping in mind the type of equipment normally found in general labs. Suggestions should focus on specific pieces of equipment or techniques you used. Vague comments such as “We should have worked more carefully” or “I should have been given a better balance” are not useful improvements.

Don’t forget to consider what exciting future experiments could be planned as a logical follow – through from this investigation. This should be presented as a potential extension to the project.

Example Individual Assessments

Investigation 1 (this is an example of a high-scoring IA)

A study on the effect of smoke water on the germination and growth of Eucalyptus pilularis

Comm: Overall the report is clear, concise and logically structured.

Comm:Subject specific terminology and notation are used throughout.

Background

Australia is a country where bushfires are commonplace during the summer season, and these fires affect much of Australia's flora. As a by-product of this, numerous native Australian plants that inhabit fire-dependent ecosystems have evolved reproductive strategies to adapt to factors associated with fire. These adaptations that affect their germination can be classified as either physical (derived from the immense heat of the bushfire stimulating a seed to germinate) or chemical (derived from a combination of various chemical elements produced by the smoke that stimulates germination).

PE:Student shows a high degree of engagement with the investigation.

Aim

The aim of this biology laboratory experiment is to explore the effects of smoke water, a mixture of water, burnt plants and hay, and its effect on the germination and post germination growth *Eucalyptus pilularis* seeds also known as gumnut or blackbutt, an Australian native plant which predominates in forests that are frequently burned.

EX:Investigation set in context and justified.
EX: Smoke water defined
EX:Research question focussed
EX:Methodology appropriate

Research question

Does smoke water stimulate germination and post germination growth of *Eucalyptus pilularis* seeds compared to de-ionized water?

Prediction

Smoke water will successfully germinate more *Eucalyptus pilularis* than de-ionized water, and thus, as a result of this, the post germination growth of the *Eucalyptus piluiaris* seeds by the smoke water will be more effective. Effectiveness, for this experiment, is defined as the height of the seedling that emerges from the germinated gumnut seed. If the various chemicals, such as phosphorous and nitrogenous compounds found in the smoky remnants of organic matter function as chemical triggers, then *Eucalyptus pilularis* will begin its germination out of its dormant state. These phosphorous and nitrogenous compounds, such as $NaN0_3$, $KN0_3$, NH_4Cl and NH_4N0_3, that are naturally occurring in organic matter, are not found in de-ionized water (Dixon et al. 1995), and hence, smoke water is predicted to germinate a larger number of seeds and grow more after germination than de-ionized water[1].

Method

Preliminary experiment

The gumnut seeds were obtained from trees growing in local forestry plantations.
It was felt necessary to find out if the gumnut seeds would germinate or not.

Ex: Defines method to collect relevant data

1. 50 seeds were planted in 5 Petri dishes of potting mixture (10 seeds per dish).
2. Each dish was watered with 10 ml of de-ionised water and left for two weeks at room temperature.
3. At the end of the two weeks the numbers of seeds germinating was counted.

Ex: Method can be easily followed and repeated by others.

Results

Number of seeds germinating = 22/50
Percentage germination = 44%
The supply of seeds was considered viable enough to proceed with the experiment.

Ex : Anticipates that method may need modifying.Sufficient data is planned for
Ex: Suitable control

An: Data displayed from trial run

An: Appropriate processing

Ev : Conclusion made from trial run.

[1] http://anpsa.org.au/APOL2/jun96-6.htmI

Equipment

- 10 Petri dishes
- 100g of "Yates premium quality" potting mix
- 5.00g of hay
- 5.00g of Eucalyptus leaves
- 5.00g of grass
- Electronic weighing scale (±0.01g)
- 100 seeds of *E. pilularis* that are 2.00 mm in diameter (±0.5mm)
- 10.0cm ruler (±0.5mm)
- 100ml of de-ionized water to create the smoke water
- 100ml of de-ionized water to create the control
- Tea strainer
- 3 x 250ml graduated beaker (±0.4mL)
- Matches
- 2 Sand baths
- 2 thermometers (±0.05°c)

To create the smoke water

1. Place 5g each of the hay, grass and Eucalyptus leaves into one of the 250ml beaker.
2. Ignite the organic matter with a match so that they catch on fire. Let them burn until they are all charred.
3. Measure 100ml of de-ionized water with the second 250ml beakers. Pour this water into the first beaker with the leaves, hay and twigs and leave to infuse for 5 hours.
4. Strain the smoke water mixture into the third measuring beaker using the tea strainer, ensuring that you are only left with the liquid remnants.
   SAFETY Care should be taken when burning the organic matter, this should be carried out in a ventilated area and the beakers should be made of heat resistance glass.

Ex: Safety risks assessed

Germination and growth

1. Set the sand baths to 30 degrees Celsius and place a thermometer in each one to verify the temperature setting.
2. Place 5 Petri dishes into one sand bath and the remaining 5 Petri dishes into another. One will be our control and one will be our test.
3. Measure out 10 x 10.0g of the potting mix using the electronic weighing scale and place 10.0g into each one of 10 Petri dishes. 5 dishes for smoke water treatment and 5 dishes for de-ionised water treatment.
4. Sow 10 gumnuts into each Petri dish and submerge them into the potting mix at a consistent depth of 0.5cm. Place the seeds towards the edges of the Petri dish so they can be observed through the glass without having to disturb the seeds to observe them.
5. Water the control sand bath at 8:15am with 10ml of de-ionized or smoke water each day for fourteen days.
6. After 14 days, count the number of seeds germinated (distinguished by the emergence of the seedling) and measure the height of the emergent seedling in the test and the control groups with the 10.0cm ruler. The seedling height is measured from the soil surface to the highest part of the stem.
7. Repeat the set up once to ensure sufficient data.

Ex: Plans for sufficient data

Ex: Plans for sufficient data

Comm: Correct definition of germination

Ex: Plans for sufficient data

Controlled Variables

- The same volume (10ml) of liquid is added to each dish at the same time (8:15am) each day throughout the 14 days.
- All 100 *E. pilularis* seeds that were used in this experiment were kept within a size range of 2.00 mm in diameter
- The water used to create the smoke water was de-ionized water like the control, which allowed consistency between the control and the test groups.

Ex: Thorough consideration of the other factors that may influence the investigation

- The temperature of the seeds was kept constant at 30.0°C by the sand baths.
- The potting mix for the seeds was from the same brand, "Yates premium potting mix" and the mass of potting mix used for the seeds was kept constant at 10.0g.
- Same amount of light was assumed to be received for each plant as the experiment was conducted in the same location on the same days.
- The seeds were placed at a depth of 0.5cm into the soil in the Petri dish.

The experiment continued for fourteen days to allow for sufficient time to gauge of the effect of the different water types, the manipulated variable. Both sand baths set at the same temperature are placed next to each other, as specified by the method, and they are assumed to be receiving equal amounts of light. The potting mix was taken from the same batch, so all samples could be assumed to contain the same ratio of ingredients. Furthermore, the *E. pilularis* was submerged into the potting mix at a consistent depth of 0.5cm and towards the edges of the Petri dish to allow for observations to be made through the glass without having to disrupt the seeds to observe them.

Our method of data collection for this experiment is to count the seeds that successfully germinated from the different Petri dishes in the control and test groups respectively, the measured variable. This is done by observing through the side of the Petri dish whether the seed coat has broken and the seedling has emerged. The other way to collect data in this experiment is to measure the height of the seedlings (from the soil surface to the seedling tip) of the germinated seeds after the 14 days of the experiment. The difference between smoke water and de-ionised water was determined using the χ^2 test for the germination and the t-test for the growth of the seedlings.

An: Appropriate method of analysis chosen

Assumptions

- The light is of the same intensity because the seeds will be set up side by side.
- The de-ionized water contains the same impurities
- The potting mix contains the same amount of its constituent components.
- The impurities and chemical elements in the air will be the same for both sets of seeds.
- The gumnut seeds are all composed of the same percentage of elements.

Observations

An: Adequate qualitative observations made

- The *E. pilularis* seeds were no bigger than 2mm, and were brownish black in colour. There were no obvious signs of previous germination, or cracking of the outer seed coat.
- The smoke water was clearly distinctive from the de-ionized water. The de-ionized water was clear, as one would expect if it had been filtered. The smoke water, however, had a blackish, straw coloured hue, due to its absorption of the remnants of the burnt organic matter.
- Definite germination was seen on a lot more seeds with the smoke water than with the de-ionized water.
- The *E. pilularis* subjected to smoke water germinated earlier on average than the seeds subjected to de-ionized water. Seeds with smoke water started showing first signs of germination as early as 7 days, when their seed coats started to split to allow the seedlings to emerge. In comparison, the de-ionized watered seeds took up to 10 days to start showing germination.
- The *E. pilularis* that were germinated by the smoke water tended to have larger seedlings emerging from the split seed coat.
- The *E. pilularis* that were watered with the smoke water had significantly larger cracking of the seed coat, allowing for more space for the seedlings to grow and extend outwards from the shell.
- The colour of the seedlings in both experiments was a distinct dark purple colour, and leaves appeared only on the smoke water experiment, with a maximum of 2 small, juvenile leaves found, measuring no more than approximately 50.0mm.

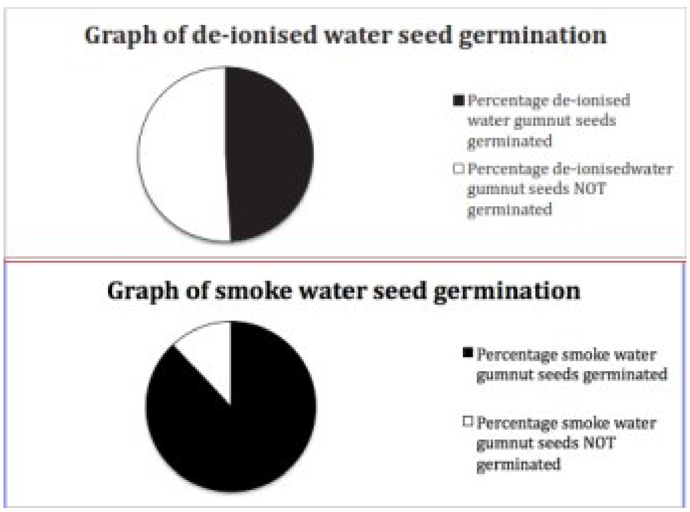
Number of seeds successfully germinated

In order to determine the number of seeds that were germinated successfully, the number of seeds that showed distinct cracking of the seed coat and the emergence of the seedling for both the smoke water and the de-ionized water test groups were counted and placed into the table below. The raw data is presented in appendix A.

Water Type	Trial	Numbers germinated (/50)	Average	%
De-ionized	1	26	25	49
	2	23		
Smoked	1	43	44	88

From the processed data that informs us about the number of seeds successfully germinated, we can clearly see that smoke water germinates, on average.

Graph of de-ionised water seed germination



Comm: Data table set in context. Clear, unambiguous presentation

Comm: Data analysis can be followed (no need for a worked example here)

An: Uncertainties missing but not considered relevant here for a count. However uncertainties ±2% could have featured for the percentage germination data.

An: Appropriate graphical presentation of processed data

Comm: Clear presentation of graph

4

X^2 test

In order to see if there is a significant difference between the germination of the seeds treated with smoke water and de-ionised water a X^2 test was carried out.

Null Hypothesis: Smoke water does not affect germination of gumnut seeds
Alternative Hypothesis: Smoke water affects germination of gumnut seeds

	Smoke water	De-ionised water	Row total
Germinated	88	49	137
Not germinated	12	51	63
Column total	100	100	200

Proportion of seed germinating = 137/200 = 68.5%
Proportion of seeds not germinating = 100 – 68.5 = 31.5%

Expected number of smoke water treated seeds to germinate = 68.5% of 100 = 68.5
Expected number of de-ionised water treated seeds to germinate = 68.5% of 100 = 68.5
Expected number of smoke water treated seeds not to germination = 31.5% of 100 = 31.5
Expected number of de-ionised water treated seeds not to germinate = 31.5% of 100 = 31.5

Observed frequency	Expected frequency	Difference	Positive difference	
O	E	O-E	IO-EI	$(IO-EI)^2/E$
88	68.5	19.5	19.5	5.55
49	68.5	-19.5	19.5	5.55
12	31.5	-19.5	19.5	12.07
51	31.5	19.5	19.5	12.07
			X^2_{calc}	35.25

Number of degrees of freedom = (rows – 1) x (columns – 1) = (2-1) x (2-1) = 1
X^2_{crit} = 3.84 for p=0.05

Since the test value for X^2_{calc} = 35.25 is a lot greater than the critical value X^2_{crit} = 3.84 we must reject the Null Hypothesis and accept the Alternative Hypothesis. The test value is significant for $p < 0.001$

Comm: Data processing can be followed.

An: Processed data correctly interpreted

An: Successful data analysis completed. Conclusion can be deduced.

5

The effect of smoke water and de-ionized water on post germination growth

This section of the experiment is designed to test the effectiveness of gumnut seed germination, depending on the type of water it received, either de-ionized or smoke water. Effectiveness was determined by the height of the seedling that emerged from the seed coat of the germinated gumnut seeds. The higher the seedling the more effective the water is on germination. The raw data is presented in appendix A.

Comm : Terminology is imprecise here. Strictly speaking this is post germination growth

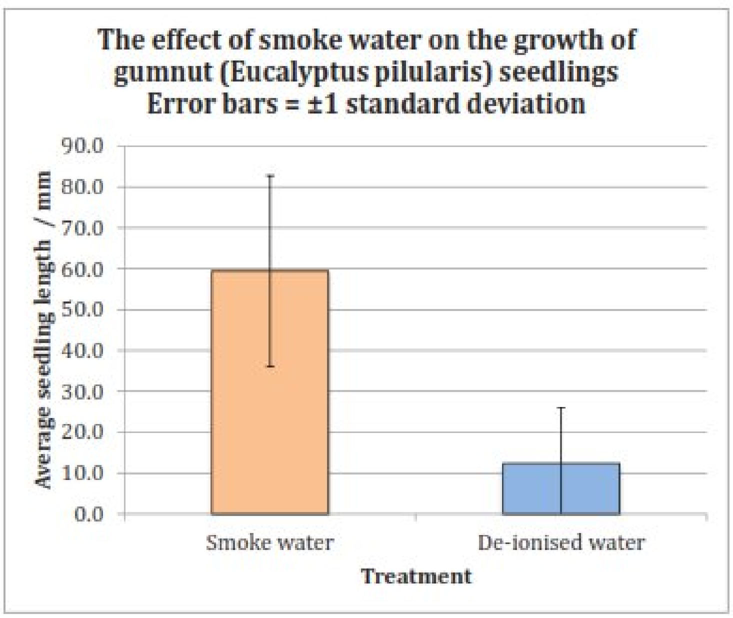
Height of seedlings for germinated seeds					
Water Type	Trial	Trial average of seedling height /mm ±0.5mm	Trial Standard Deviation	Overall average height /mm ±0.5mm	Overall standard deviation
De-ionized	1	13.0	13.4	23.4	13.6

Comm: Data table set in context. Clear, unambiguous presentation. Processing can be followed, a worked example is not expected here. Processing can be followed. Correct conventions for uncertainties

On first observation of the processed data, it can be seen that smoked water clearly has a higher average seedling height than the de-ionized water whilst also having a lower standard deviation. This indicated that the smoked water seeds seedling grew higher than the de-ionized water. The error bars in the graph below ionised water treatment trials. To verify this, a t-test was carried out on the data.

An: The candidate considers the reliability of the data though it could be argued that ungerminated seeds should not be included here. These results (0cm growth) skew the distribution so that it is not normally distributed.

6



t-test

In order to statistically test whether the shoot of smoke water germinated gumnut seedlings grew more than the de-ionized water, a two-tailed t-test for independent samples was carried out to investigate whether there is a significant difference between the growth of the seedlings.

- Null Hypothesis - the smoke water has no effect on post germination growth of the gumnut seedlings.
- Alternative Hypothesis - the smoke water does have an effect on post germination growth of the gumnut seedlings.

An: Appropriate method of analysis chosen.

t-test formula:

degrees of freedom = $n_1 + n_2 - 1 = 198$
$t_{calc} = 17.4$
t_{crit} $(p=0.05) = 1.97$

Because our test t value $t_{calc} = 17.4$ is greater than the critical value $t_{crit} = 1.97$ at $p = 0.05$, we can accept the alternative hypothesis, that the smoke water significantly stimulates the growth of the gumnut seedlings germinated. The test value is significant for $p < 0.001$

Comm: Processing can be followed.

An: Successful data analysis and interpretation completed

Evaluation of Weaknesses with suggested improvements

The potting mixture used was obtained from the local garden shop, and whilst the same brand and the same amount of the potting mixture was used for both seeds in the experiment, the potting mixture may have contained impurities which could potentially have enhanced or reduced the ability of the seeds to germinate, especially because the Yates brand "Contains trace elements to add extra vital nutrients"[2]. Some of the chemicals from the smoke water also could have potentially reacted with some of the ingredients of the potting mix and rendered them useless, however the seeds watered with de-ionized water may not have had this potential problem. To improve this, I could have used a different support for the seeds such as cotton wool or filter paper.

Ev: Student considers the reliability of the data and considers the impact of experimental uncertainty

Ev: Sensible suggested improvement.

Using different types of leaves, twigs and hay to create the smoke water would give you different chemicals, as each has a differing composition of chemicals, some of which may be beneficial for germination, and some of which wouldn't. For this experiment, I could have used only one variable like hay, instead of twigs and leaves as well. This would narrow my scope of results down as well and I would potentially be able to pinpoint the specific chemical, or source of the chemical, that allows gumnuts to germinate successfully. It may be found that twigs, for example, don't enhance seed germination but leaves do. By singling out the element that best enhances seed enhances the seeds germination.

Ev: Feasible extension proposed.

Combined with this, I could have used gumnut seeds that were all the same weight rather than the same size in diameter. I tried to use gumnut seeds that were only 2.00mm in diameter, however it would have been better served to use seeds that all had a constant weight of 0.2g for example, as then I could have assumed that each seed contained the same amounts and composition of nutrients, enzymes and other chemicals inside it.

Ev: Suggested improvement impractical

Ev: Unsafe assumption

To further narrow my scope of the experiment, I could have tested the effects of different concentrations of the smoke water as well. Instead of only using a 1:10 ratio of 1 part twigs, hay and leaves to 10 parts de-ionized water, I could have tested a ratio of 1:5 with 1 part twigs, hay and leaves and 5 parts de- ionized water. Working out the optimum concentration of smoke water would help this experiment as better and clearer results could be obtained.

Ev: Feasible extension proposed.

[2] http://www.yates.com.au/products/pots-and-potting-mix/all-purpose-potting-mix/yates-premium-potting-mix/

7

Conclusion

In conclusion, the experiment supported my hypothesis that smoke water will successfully germinate more *Eucalyptus pilularis* than de-ionized water. Furthermore, the subsequent growth of the *Eucalyptus pilularis* seeds by the smoke water was found to be more effective than the de-ionized water due to the significantly taller seedlings of the *Eucalyptus pilularis* that were exposed to the smoke water. This could because the various chemicals, such as phosphorous and nitrogenous compounds found in the smoky remnants of the burnt organic matter (in my case, the burnt leaves, hay and twigs) acted as chemical triggers for the *E. pilularis* to begin its germination out of its dormant state and stimulate its subsequent growth. While all of the active compounds in smoke have not yet been identified, a large majority of the compounds present in the smoke water mixture ($NaN0_3$, $KN0_3$, NH_4Cl and NH_4N0_3) are water soluble, thus they are easily able to be taken in by the gumnut seed and, once inside the seed, they are used as these so called "chemical triggers" to start germination. These chemical triggers work by altering the levels of chemicals that the seed maintains in homeostasis, once the seed has registered these differing levels of phosphorous and nitrogenous compounds, it stimulates the germination of the seed. There are, however, compounds called *butenolides* that have confirmed germination-promoting action. These *butenolides* are produced by some plants on exposure to high temperatures and smoke caused by bush fires. In particular, botanists Flematti, Ghisalberti, Dixon and Trengove isolated a particular *butenolide* called 3-methyl-2H-furo[2,3-c]pyran-2-one, which was found to trigger seed germination in plants whose reproduction is fire-dependent, such as the *E. pilularis* used in my experiment[3]. One theory about how this *butenolide called* 3-methyl-2tf-furo[2,3-c]pyran-2-one is formed by the plant is given to us by Light, Berger and van Steden, who hypothesized that this particular *butenolide* was created from cellulose within the plant, and this substance, created by the cellulose, stimulated the seeds reproductive cycle, and hence, germination[4]. The two pie graphs that show the percentage of seeds germinated for the smoke water experiment and de-ionized water experiment respectively, furthermore indicate that my hypothesis was correct, with 88% of the smoke watered seeds successfully germinating compared to only 47% of the de-ionized water seeds germinating. This was backed up with my χ^2-test that accurately concluded that we could reject the null hypothesis, with a 95% degree of confidence, that the smoke water successfully germinated more seeds that the de-ionized water. The t-test on the seedling growth shows that the smoke water has a significant positive effect on the gumnut seedlings.

Ev: Compare to relevant scientific theory

Ev : Successful interpretation of the results. Relevant justified conclusion drawn

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Marnie E. Light, Barend V. Burger and Johannes van Staden Formation of a Seed Germination Promoter from Carbohydrates and Amino Acids http://pubs.acs.org/doi/abs/10.1021/jf050710u *J. Agric. Food Chem.*, 2005, *53* (15), pp 5936–5942 Publication Date (Web): July 1, 2005

[3] http://www.sciencemag.org/content/305/5686/977
[4] http//pubs.acs.org/doi/abs/10.1021/jf050710u

Appendix A - raw data tables

Seeds watered with Smoke Water (Trial 1)

An: Raw data recorded includes uncertainties

Seed Number	Did the seed Germinate	Height of seedling in / mm ±0.5mm
1	Yes	56.0
2	Yes	71.0
3	Yes	73.0
4	Yes	67.0
5	Yes	54.0
6	No	0
7	Yes	58.0
8	Yes	70.0
9	Yes	66.0
10	Yes	61.0
11	Yes	64.0
12	Yes	71.0
13	No	0
14	No	0
15	Yes	59.0
16	Yes	67.0
17	Yes	58.0
18	Yes	63.0
19	Yes	62.0
20	Yes	64.0
21	Yes	72.0
22	Yes	75.0
23	No	0.0
24	Yes	68.0
25	Yes	64.0
26	Yes	69.0
27	Yes	70.0
28	No	0
29	Yes	52.0
30	No	0
31	Yes	79.0
32	Yes	81.0
33	Yes	83.0
34	Yes	74.0
35	Yes	74.0
36	Yes	78.0
37	Yes	63.0
38	Yes	69.0
39	Yes	58.0
40	Yes	70.0
41	Yes	68.0
42	Yes	62.0
43	Yes	63.0
44	Yes	68.0
45	Yes	58.0
46	Yes	81.0
47	Yes	68.0
48	Yes	73.0

Investigation 1: Moderator comments

Personal engagement x/2	Exploration x/6	Analysis x/6	Evaluation x/6	Communication x/4	Total x/24
2	5	5	5	4	21

Personal engagement

Mark	Descriptor
2	The justification given for choosing the research question and/or the topic under investigation demonstrates personal significance, interest or curiosity. There is evidence of personal input and initiative in the designing, implementation or presentation of the investigation. 2
Moderator's award 2	Moderator's comment The research question is justified and there is clear indication of personal engagement. Though the experiment employs a standard test for seed germination and the measurement of post germination growth, they have been used in an applied manner to solve the problem of a control. The experiment took place over an extended period of time requiring considerable personal input.

Exploration

Mark	Descriptor
5–6	The topic of the investigation is identified and a relevant and fully focused research question is clearly described. 6 The background information provided for the investigation is entirely appropriate and relevant and enhances the understanding of the context of the investigation. 5 The methodology of the investigation is highly appropriate to address the research

	question because it takes into consideration all, or nearly all, of the significant factors that may influence the relevance, reliability and sufficiency of the collected data. 5 The report shows evidence of full awareness of the significant safety, ethical or environmental issues that are relevant to the methodology of the investigation. 6
Moderator's award 5	Moderator's comment The research question is focused and relevant background information is provided, however, more information on the interaction of the minerals identified with germination would be needed. The methodology is highly appropriate to the research question providing sufficient control and data, though the pH of the smoke water ought to have been monitored. Safety issues are considered. The experiment presents no ethical or environmental issues.

Analysis

Mark	Descriptor
3–4	Appropriate and sufficient data processing is carried out that could lead to a broadly valid conclusion but there are significant inaccuracies and inconsistencies in the processing. 4
5–6	The report includes sufficient relevant quantitative and qualitative raw data that could support a detailed and valid conclusion to the research question. 6 The report shows evidence of full and appropriate consideration of the impact of measurement uncertainty on the analysis. 6 The processed data is correctly interpreted so that a completely valid and detailed conclusion to the research question can be deduced. 6
Moderator's award 5	Moderator's comment Sufficient relevant quantitative and qualitative data is collected to support a detailed and valid conclusion. These data are appropriately and successfully processed most of the time with consideration of the uncertainties. However, it is not certain that data for heights follows a normal distribution therefore the t-test may not be valid. The processed data are correctly interpreted.

Evaluation

Mark	Descriptor
5–6	A conclusion is described and justified which is relevant to the research question and supported by the data presented. 6 A conclusion is correctly described and justified through relevant comparison to the accepted scientific context. 6 Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are discussed and provide evidence of a clear understanding of the methodological issues involved in establishing the conclusion. 5 The student has discussed realistic and relevant suggestions for the improvement and extension of the investigation. 5
Moderator's award 5	Moderator's comment A relevant conclusion, justified through comparison with scientific literature values, is drawn and is supported by the data. The investigation is evaluated and there is some consideration of the uncertainties and the limitation of the data and the experiment. However, there are some assumptions made that may not have a strong foundation, for example, the candidate assumes that the different seed masses will necessarily have different nutrient contents. The suggested improvements are generally sensible though selecting seeds of exactly the same mass is not realistic. Feasible extensions are proposed.

Communication

Mark	Descriptor
3–4	The report is well structured and clear: the necessary information on focus, process and outcomes is present and presented in a coherent way. 4 The report is relevant and concise thereby facilitating a ready understanding of the focus, process and outcomes of the investigation. 4 The use of subject-specific terminology and conventions is appropriate and correct. Any errors do not hamper understanding. 4
Moderator's award 4	Moderator's comment The report is coherent and complete. It is relevant and reasonably concise. There are no major or consistent errors in subject-specific terminology or conventions.

Investigation 2: Moderator comments

Personal engagement x/2	Exploration x/6	Analysis x/6	Evaluation x/6	Communication x/4	Total x/24
2	5	6	5	3	21

Personal engagement

Mark	Descriptor
2	The justification given for choosing the research question and/or the topic under investigation demonstrates **personal significance, interest or curiosity**. 2 There is evidence of **personal input and initiative** in the designing, implementation or presentation of the investigation. 2
Moderator's award 2	**Moderator's comment** Though there is only a little indication of personal significance, there is clear evidence of personal input during the design and implementation.

Exploration

Mark	Descriptor
3–4	The topic of the investigation is identified and a relevant but not fully focused research question is described. 4 The report shows evidence of some awareness of the significant **safety,** ethical or environmental issues that are **relevant to the methodology of the investigation*. 4**
5–6	The background information provided for the investigation is entirely appropriate and relevant and enhances the understanding of the context of the investigation. 6 The methodology of the investigation is highly appropriate to address the research

	question because it takes into consideration all, or nearly all, of the significant factors that may influence the relevance, reliability and sufficiency of the collected data. 5
Moderator's award 5	**Moderator's comment** The aim is focused but there is no direct link established between the resting position of the moths discussed in the introduction and the light levels varied in the experiment. The scientific context is established. The method is straightforward with good control of variables. Some additional information on the simulation would be helpful but the screen shots are useful. There are no safety, ethical or environmental issues.

Analysis

Mark	Descriptor
5–6	The report includes sufficient relevant quantitative and qualitative raw data that could support a detailed and valid conclusion to the research question. 5 Appropriate and sufficient data processing is carried out with **the accuracy** required to enable a conclusion to the research question to be drawn that is fully **consistent** with the experimental data. 6 The report shows evidence of full and appropriate consideration of the impact of measurement uncertainty on the analysis. 6 The processed data is correctly interpreted so that a completely valid and detailed conclusion to the research question can be deduced. 6
Moderator's award 6	**Moderator's comment** Sufficient raw data is collected. Some qualitative observations appear in the discussion (for example, fingerprints on the screens). The processing is sufficient, appropriate and accurately carried out. There is appropriate consideration of uncertainties in the calculation of the standard deviations. The interpretations of the graphs and t-tests are correct.

Evaluation

Mark	Descriptor
5–6	A conclusion is **described and justified** which is relevant to the research question and supported by the data presented. 5 A conclusion is correctly **described and justified** through relevant comparison to the accepted scientific context. 6 Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are **discussed** and provide evidence of a clear understanding of the**methodological issues** involved in establishing the conclusion. 6 The student has **discussed** realistic and relevant suggestions for the improvement and extension of the investigation. 5
Moderator's award 5	**Moderator's comment** Several conclusions are made that are relevant and supported by the data though it could be more fully explained. The conclusions are supported by reference to accepted scientific context. Strengths and weaknesses of the investigation are considered with respect to the capacity of the simulation to mimic a natural event. The observed superior performance of the melanic form suggests this simulation is biased; this should lead to a suggested improvement.

Communication

Mark	Descriptor
3–4	The report is well structured and clear: the necessary information on focus, process and outcomes is present and presented in a coherent way. 3 The report is relevant and concise thereby facilitating a ready understanding of the focus, process and outcomes of the investigation. 3 The use of subject specific terminology and conventions is appropriate and correct. Any errors do not hamper understanding. 4
Moderator's award 3	**Moderator's comment** The report is generally well structured and relevant though it could be clearer in places and more concise. The terminology and conventions are appropriate and correct.

Uncertainty

When you record a scientific measurement, the last digit that you record is understood to have some uncertainty, and to be your best estimate. When reading non-electronic devices such as rulers, thermometers, and glassware, the general rule of thumb is to "read between the lines"! This means that you can estimate one more digit or decimal place than the device is marked. But this rule does not apply to electronic equipment (such as a balance or electronic thermometer) which gives you a direct digital readout. For these digital devices, the product instructions or manual will provide you the precision of the instrument (see data logger uncertainties section).

The following uncertainties apply to careful measurements made by a trained observer:

Length (common metric rulers): +/- 0.01 cm (or 0.1 mm)

Mass (electronic balances): always +/- one unit in the last digit. This means that a common centigram balance is +/- 0.01 grams; a milligram balance +/- 0.001 grams.

Volumetric Glassware

- 10 mL graduated cylinder: +/- 0.02 mL (always record to 2 decimal places)
- 25 mL graduated cylinder: +/- 0.1 mL (always record to 1 demical places)
- 100 mL graduated cylinder: +/- 0.5 mL (always record to 1 decimal place)
- 500 mL graduated cylinder: +/- 5 mL
- 50 mL buret: +/- 0.02 mL (always record to 2 decimal places)
- 10 mL graduated pipet: +/- 0.01 mL (always record to 2 decimal places)
- Fixed volume pipets (glass): +/- 0.2 % of the capacity (Ex: 25 mL = +/- 0.05 mL)

Beakers and Flasks: Approximately 5% of the capacity. These should not be used to measure precise amounts

Thermometer: when alcohol or mercury: +/- 0.2 ^{o}C

Error Analysis

There are two types of error or uncertainty that will always limit the precision and the accuracy of our results. The two types are called random error and systematic error.

- Random error comes from the measuring device itself and depends upon its <u>precision</u>. All measuring devices produce some uncertainty in the last measured digit. We cannot eliminate random error <u>totally</u>. But we can <u>minimize it</u> by using good measuring devices and more importantly, reading them carefully and skillfully to as many significant digits as they allow.

- Systematic error refers to errors or limitations that can be avoided. They might be due to an improperly calibrated instrument. Or perhaps we are not reading the instrument correctly. Finally (and most often), perhaps our experimental method was flawed and can be improved by more careful experimental design.

To Deal with Error and Uncertainty follow these four steps:

- When recording your data, also record the precision (+/-) for all measurements due to random error, depending on the measuring device. You can do this either by writing the +/- value after each measurement or by including the +/- value in the heading of a data table column.
- Do your calculations to obtain your experimental result.
- Using the uncertainties in each data element, calculate the percent uncertainty in your result that is due to random error alone.
- If relevant take the literature value of the result and calculate the percent error between your value and the literature value.
- Compare the results of steps (c) and (d) to decide whether random error alone can account for how far you were off the literature value, or whether systematic error also affected your results.

Calculating the Uncertainty of a Numerical Result

When you add or subtract data, the uncertainty in the result is the sum of the individual uncertainties. Convert this sum to a percentage.

Example 1:	Mass of crucible + product:	74.10 g	+/- 0.01 g
	Mass of empty crucible:	72.35 g	+/- 0.01 g
	Mass of product	1.75 g	+/- 0.02 g

The individual uncertainties are added to give +/- 0.02 g for the result. Converting to a percentage, (0.02 g / 1.75 g) x 100 = 1 %. This is the percent uncertainty due to random error.

Standard Deviation

Biological systems, because of their complexity and normal variability, require replicate observations and multiple samples of material. As a rule, the lower limit is five measurements, or a sample size of five. Very small samples run from 5 to 20, average samples run from 20 to 30, and big samples run from 30 upwards. Obviously, this will vary within the limits of the time available for your investigation.

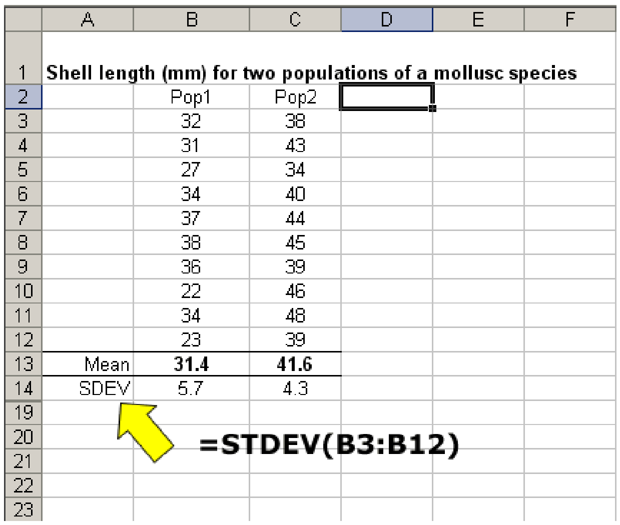
Where sufficient replicates have been carried out, then the calculation of the standard deviation of the mean is expected.

Some of the following text has been modified from Wikihow 2015, http://www.wikihow.com/Calculate-Standard-Deviation, Accessed April 2015

Standard deviation is a measure of the spread of the data about the mean value. It provides a measure of the ‘typical’ amount that the values differ from the mean. Between them, the mean and standard deviation provide a good summary of a set of normally distributed data. (Normally distributed data are data that, if presented in a tally chart or plotted in a frequency histogram, form a symmetrical bell-shaped graph.)

Calculating standard deviation

There are two ways of calculating standard deviation. The first is by using excel which will carry out the calculations for you



	A	B	C	D	E	F
1	Shell length (mm) for two populations of a mollusc species					
2		Pop1	Pop2			
3		32	38			
4		31	43			
5		27	34			
6		34	40			
7		37	44			
8		38	45			
9		36	39			
10		22	46			
11		34	48			
12		23	39			
13	Mean	**31.4**	**41.6**			
14	SDEV	5.7	4.3			
19						
20		=STDEV(B3:B12)				
21						
22						
23						

1. Place your sufficient raw data in an excel worksheet
2. At the end of the data column or row, in an empty sheet type =stdev(
3. Highlight a single raw/column of data and then close the bracket)
4. If done correctly the standard deviation value will be displayed

The second way is to calculate the Standard deviation yourself.

1. Set out the raw data in the first column of a table and then work out the mean (x) by dividing the sum by the number of samples (n).

2. Work out the deviation of each piece of data from the mean n – x. This will give you a figure of how much each data point differs from the mean.

For example, in our sample (10, 8, 10, 8, 8, and 4) the mean or mathematical average was 8.

10 - 8 = 2; 8 - 8 = 0, 10 - 8 = 2, 8 - 8 = 0, 8 - 8 = 0, and 4 - 8 = -4.

3. Square all of the numbers from each of the subtractions you just did. You will need each of these figures to find out the variance in your sample.

Remember, in our sample we subtracted the mean (8) from each of the numbers in the sample (10, 8, 10, 8, 8, and 4) and came up with the following: 2, 0, 2, 0, 0 and -4.To do the next calculation in figuring out variance you would perform the following: 2^2, 0^2, 2^2, 0^2, 0^2, and $(-4)^2$ = 4, 0, 4, 0, 0, and 16.

4. Add the squared numbers together. In the example above the results would be 24.

5. Divide the sum of squares by (n-1). Remember, n is how many numbers are in your sample. Doing this step will provide the variance. In our sample of test scores (10, 8, 10, 8, 8, and 4) there are 6 numbers. Therefore, n = 6. n-1 = 5. Remember the sum of squares for this sample was 24.

24 / 5 = 4.8 The variance in this sample is thus 4.8.

6. Take the square root of the variance. This figure is the standard deviation. At least 68% of all the samples will fall inside one standard deviation from the mean. The variance was 4.8. $\sqrt{4.8} = 2.19$. The standard deviation in our sample is therefore 2.19.

5 out of 6 (83%) of our sample of test scores (10, 8, 10, 8, 8, and 4) is within one standard deviation (2.19) from the mean (8)

SI unit table and some of the rules concerning the correct use of SI unit

From Flinn Scientific inc. (2006), International System of Units image, http://www.flinnsci.com/store/catalogPhotos/AP6899cat.jpg, Accessed April 2015

International System of Units (SI)

SI Base Units

Base Quantity	Name	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

SI Derived Units

Derived Quantity	Name	Symbol	Equivalent SI units
Frequency	hertz	Hz	s^{-1}
Force	newton	N	$m{\cdot}kg{\cdot}s^{-2}$
Pressure	pascal	Pa	N/m^2
Energy	joule	J	N·m
Power	watt	W	J/s
Electric charge	coulomb	C	s·A
Electric potential	volt	V	W/A
Electric resistance	ohm	Ω	V/A
Celsius temperature	degree Celsius	°C	K*

*Unit degree Celcius is equal in magnitude to unit kelvin.

SI Prefixes

Factor	Name	Symbol	Numerical Value
10^{12}	tera	T	1 000 000 000 000
10^{9}	giga	G	1 000 000 000
10^{6}	mega	M	1 000 000
10^{3}	kilo	k	1 000
10^{2}	hecto	h	100
10^{1}	deka	da	10
10^{-1}	deci	d	0.1
10^{-2}	centi	c	0.01
10^{-3}	milli	m	0.001
10^{-6}	micro	µ	0.000 001
10^{-9}	nano	n	0.000 000 001
10^{-12}	pico	p	0.000 000 000 001

• Adapted from NIST Special Publication 811
• SI rules and style conventions recommend using spaces rather than commas to separate groups of three digits.

Uncertainties of lab sensors

PASCO Temperature sensor - ±0.5 °C

PASCO pH probe - ±0.1 (after calibration)

PASCO Dissolved oxygen probe - ±0.2 mg/L after calibration Accuracy

PASCO Conductivity sensor - 0 to 1,000 µS/cm, 0 to 10,000 µS/cm, 0 to 100,000 µS/cm

PASCO Voltage sensor - ±50mV at 10 V accuracy

PASCO Current sensor- ±5mA at 1 A accuracy

PASCO Barometer sensor - ±0.001 in. Hg Resolution

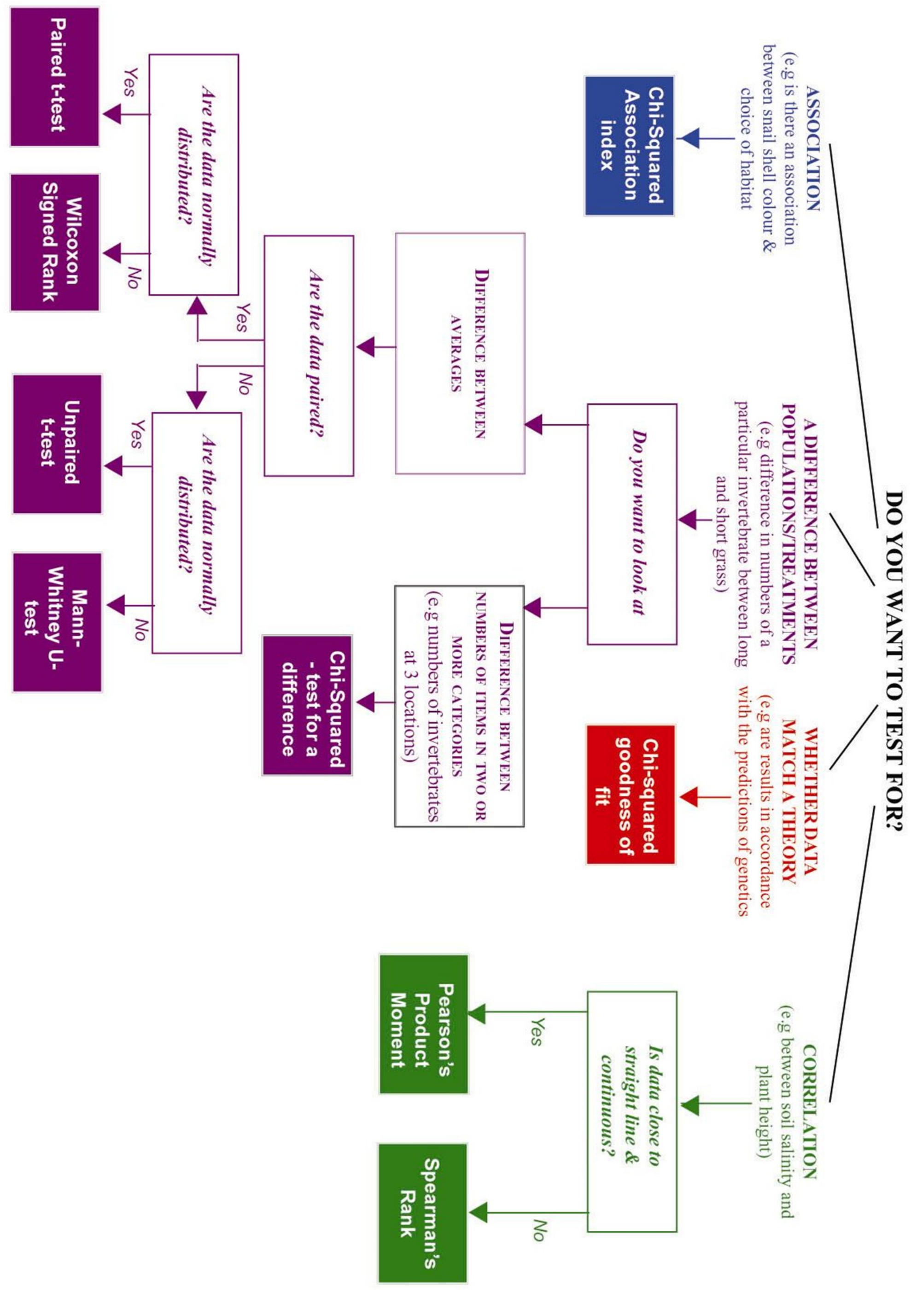
PASCO Humidity sensor - ± 2%

PASCO Dew point sensor - ± 2%

PASCO Altitude sensor - 0 to 7,000 m ±5%

PASCO Acceleration sensor – Resolution 0.002g

Statistics



DO YOU WANT TO TEST FOR?
ASSOCIATION
(e.g is there an association between snail shell colour & choice of habitat
Chi-Squared Association index
A DIFFERENCE BETWEEN POPULATIONS/TREATMENTS
(e.g difference in numbers of a particular invertebrate between long and short grass)
Do you want to look at
DIFFERENCE BETWEEN AVERAGES
Are the data paired?
Yes
No
Are the data normally distributed?
Yes
No
Paired t-test
Wilcoxon Signed Rank
Are the data normally distributed?
Yes
No
Unpaired t-test
Mann-Whitney U-test
DIFFERENCE BETWEEN NUMBERS OF ITEMS IN TWO OR MORE CATEGORIES
(e.g numbers of invertebrates at 3 locations)
Chi-Squared - test for a difference
WHETHER DATA MATCH A THEORY
(e.g are results in accordance with the predictions of genetics
Chi-squared goodness of fit
CORRELATION
(e.g between soil salinity and plant height)
Is data close to straight line & continuous?
Yes
No
Pearson's Product Moment
Spearman's Rank

The following text has been modified from Salters-Nuffield Advanced Biology, Harcourt Education Ltd 2006. ©University of York Science Education Group.

When undertaking any investigation, much mental anguish will be saved if you can go straight into using an appropriate statistical test because you have planned what you are going to do and collected the right sort of data. There are several types of statistics including:

- Descriptive statistics such as the mean or the median; they tell you something about a set of data (i.e. the average and middle values in this case).
- Hypothesis testing statistics such as a t-test or a χ^2 test; these tests compare one set of data with another set of data.

Invent a null hypothesis

In normal English a hypothesis is a statement that you think explains your observations.

For instance, you are walking down the street and notice three giraffes, a stoat and an elephant fighting outside a restaurant. What could possibly explain this bizarre phenomenon?

You could invent several hypotheses:

Hypothesis 1: Someone has spiked your mineral water with hallucinogenic drugs.

Hypothesis 2: They're filming the 14th series of Animal Hospital and it's all gone horribly wrong.

Hypothesis 3: The Chief Zookeeper has left the main gate unlocked again.

These are all possible explanations for your observations.

In hypothesis-testing statistics you start with a special sort of hypothesis that you set up purely for the purpose of the test. It is called a null hypothesis (symbol: H).

All of the tests compare one set of data with another set of data. A null hypothesis is a statement that says that there is no significant difference between the two sets of data.

This statement 'of no significant difference' is always made even if you think there really is a significant difference.

Let us imagine you are comparing the mean lengths of trunks of African elephants and Indian elephants. It looks pretty clear to you from Figure 1 on the next page that the African ones are longer by far. However, you would state your null hypothesis as follows:

There is no significant difference in mean trunk length between African and Indian elephants.

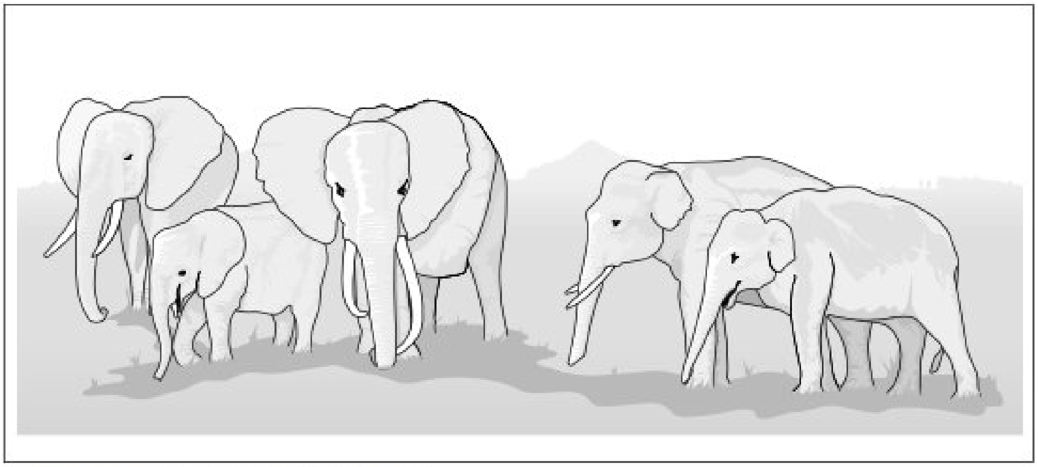


Figure 1 How are these elephants different?

Always stating there is no difference may seem peculiar until you get used to it. The point is that in the end you get to either accept the null hypothesis if there is no significant difference, or reject it if there is a significant difference. Even more thrillingly, you get to pick how certain you want to be that you are correct in accepting or rejecting the null hypothesis; this is the real value of such tests.

Null hypotheses are sometimes called hypotheses of no difference because you always state them this way. Null means nothingness, lacking distinction, characterless, i.e. no difference.

Calculate the value of the test statistic

The value of the test statistic is the number you calculate from your data. It will have a name that depends on the test you are using (e.g. ‘t’ or ‘*r*’). It is called the calculated value of the test statistic. The procedures for working these numbers out are to be found on the Maths/stats support sheet for the individual tests (10 Standard deviation (M0.10S), 11 t-test (M0.11S), 12 Spearman’s rank correlation (M0.12S), 13 (Chi-squared) test(M0.13S), 14 Mann-Whitney U test (M0.14S)).

Work out the critical value of the test statistic

Next, you obtain a table of critical values for the appropriate test (supplied by statisticians who have worked out all combinations of circumstances and sets of data). You extract from the table the critical value that applies to your combination of circumstances, which depends on the size of your sets of data and the degree of precision you require in your acceptance or rejection of your null hypothesis.

At this point you need to have chosen how certain you want to be that you are correct in your acceptance or rejection of H. Many tables of critical values have significance levels (given as percentages or probabilities along the top). You can pick any of them but the smaller the percentage significance level you pick, the more certain you will be that you are correct in rejecting H.

For example: If you chose to test at the 1% significance level (p0.01), on 99% of the occasions that you reject H you are likely to be correct. About 1% of the time you will conclude that a significant difference exists when it actually doesn't. It's rather like saying you're 99% certain if you find a significant difference that you are correct.

In biology, because of the inherent variability of biological systems, it is generally accepted that a significance level of 5% is absolutely fine. This means that if you did the same investigation lots of times you'd expect the same result when you perform the statistical test 95% of the time and a different result due to chance 5% of the time. It's like saying you're 95% certain that if you reject H you are correct.

Compare the calculated value with the critical value

You now compare the calculated value with the critical value; depending on which one is the bigger, you either accept or reject your opening null hypothesis. You do this in the happy knowledge that you would expect this result 95% (or whatever significance level you pick) of the time if you repeated the investigation forever.

Deciding which statistical test to use

Beware, there is nothing worse than doing your experimental work or fieldwork only to find that the results you have collected are useless for the statistical test you need to use to test your hypothesis. So, once you have come up with your idea for an investigation (often the hardest part), done your background research and formulated your null hypothesis, you need to decide what sort of data you will collect. You need to know what sort of data you will have before you can select the correct test. There are several types of data.

<u>Interval data</u>

This is best thought of as 'real' measurements of things. Length is a good example of interval data. If you have two pieces of data and you can say how much bigger or smaller one is than the other, then you have interval data. For example, an elephant's trunk of 2 metres length is 1 metre longer than an elephant's trunk of 1 metre length.

<u>Ordinal data</u>

Let us suppose that you were surveying elephant's trunks but were too nervous to get close enough to measure them directly. You could devise a scale thus:

1 = embarrassingly small

2 = short

3 = medium

4 = long

5 = very long

6 = probably works for Fire Brigade.

You could assess trunk lengths at a safe distance and you could say that a trunk rated at level 3 was shorter than a 4 (or whatever) but you could not say by how much. This is an example of ordinal data, where the numerical value gives the relative position in a series but does not tell you about the size of the interval between the measurements.

Categorical data

Some kinds of data comprise counts of things in categories; these are categorical data. For example, during your elephant trunk studies you notice that some animals have flared nostrils (possibly as a result of over-zealous water squirting) and some have compact nostrils. Each individual belongs in one of these two categories and you could count the frequency of occurrence of each type; e.g. frequency of flared nostril individuals = 20, frequency of compact nostril individuals = 22.

t-test

A t-test will tell you if the means of two sets of normally distributed (symmetrical about the mean), unmatched, (see Spearman's rank correlation below for what this means) continuous data with interval level measurements are significantly different to one another. (If you have a big sample, 25+, you can use it for ordinal data as well.)

For any t-test you do the null hypothesis will be:

There is no significant difference between the means of the two sets of data.

Examples of where you might use a t-test:

- comparing mean heights of limpets on two different seashores
- comparing mean masses of plants grown with and without fertiliser
- comparing mean tree heights on North- and South-facing slopes
- comparing mean vegetation heights on trampled and untrampled areas
- comparing mean vitamin C contents of pasteurised and unpasteurised orange juice.

Spearman's rank correlation

A Spearman's rank correlation test will tell you whether two variables are correlated, i.e. whether a change in one variable is accompanied by a change in the other variable. It will tell you whether the relationship is a positive correlation (both go up together) or a negative correlation (one goes up as the other goes down) and the strength of any correlation.

For any Spearman's rank correlation you do, the null hypothesis will be:

- There is no correlation between the two variables.

You can use this test on interval or ordinal data and the data will always be in matched pairs. This means that one piece of data is associated with one other piece of data only, for example, if you were measuring temperature and water depth, each temperature measurement would belong with only one specific depth measurement (both taken at the same place). If you mixed the matched pairs up the data would be meaningless.

Examples of where you might use Spearman's rank correlation:

- Is there a correlation between temperature and height up a mountain?
- Is there a correlation between mouse density and proximity to a cheese factory?
- Is there a correlation between current speed and mayfly nymph abundance?
- Is there a correlation between cigarette smoking and low intelligence?
- Is there a correlation between species diversity and height on the seashore?

χ^2 test (Chi-squared test)

A χ^2 test does a lot of things but it can be used in a simple way to see if an observed set of data (categorical data, counts of things in categories, i.e. frequencies) differs significantly from what we might expect, given our null hypothesis. For example, it can be used in a genetics experiment to compare the observed data with what might be expected from a cross between two heterozygotes.

For any χ^2 test you do the null hypothesis will be:

There is no significant difference between the observed and the expected frequencies.

Examples of where you might use a χ^2 test:

- Do seashore snails actively select specific microhabitats?
- Does lichen frequency differ between air-polluted and clean sites?
- Are the fruit flies in the lab heterozygous?

Mann-Whitney U test

The Mann-Whitney U test tests for differences between population medians. You can use it on interval or ordinal level data that are not in matched pairs (see Spearman's rank test above). The data don't have to be normally distributed but the distributions have to be the same shape. It can be used on a great many datasets and is one of the most popular statistics used in A Level coursework. It has the great advantage in that it's fairly easy to do as well.
For any Mann-Whitney U test you do the null hypothesis will be:

There is no significant difference between the medians of the two populations.

Examples of where you might use a Mann-Whitney U test:

- To compare median trunk lengths in two populations of elephants. (You could use interval or ordinal data as described in the example on page 3.)
- To compare median body masses of members of 'Chocolate Guzzlers Anonymous' and the 'Lettuce Nibblers Association'.
- To compare the median density of limpets on the middle shore with the median density of limpets on the upper shore.
- To compare the median diversity of lichens in the town centre with the median diversity of lichens in the countryside.

Lab safety: general rules in the Laboratory / risk assessment

1: No eating or drinking in the lab

2: Use good microbiological practice

3: Keep flame and flammable solutions far apart

4: Keep electrical equipment far from water

5: Check the Chemical hazcards for individual chemical safety procedures

6: Use proper safety protection , for example fume hood, goggles and gloves

7: Always clean glassware before you use it to be sure that residues are cleaned away

8: Be careful weighing out chemicals and reagents. Do not return excess materials to the stock container

9. Know your hazard symbols

10: Check all waterbaths with a thermometer before putting your hand into water

11: All sharps (needles, razors, pins, toothpicks) should be discarded in a sturdy container

12. Be aware of your surroundings and the safety equipment present

Risk Assessments

CLEAPSS, Making and recording risk assessments in school science, GL 90 PTB 12/09, CLEAPS.org.uk Accessed April 2015

A risk assessment just be consulted or made before an activity is carried out.

• Identify the hazards From warning signs and symbols, general knowledge, model risk assessment, knowing the person(s) involved, the environment (including time pressures), and those posed by unusual circumstances.

• Assess the risks. How likely is it that the procedure could go wrong? How serious would it be if it did go wrong? How many people would be affected?

• Reduce the risk by adopting control measures. It is a requirement to reduce all risks to those as low as possible which still allow the desired end to be achieved. For example, substitute a safer substance, segregate users from the event, use person protective equipment or take other measures identified on the model risk assessment.

IB animal experimental policy

The IB policy is more stringent than national standards for experimentation in schools. Bearing in mind its mission statement, the IB is in the vanguard of ethical behaviour.

Any planned and actual experimentation involving animals must be subject to approval following a discussion between you and your teacher based on the IB animal experimentation policy.

Experiments involving animals must be based on observing and measuring aspects of natural animal behaviour. Any experimentation should not result in any pain or undue stress on any animal (vertebrate or invertebrate) or compromise its health in any way. Therefore experiments that administer drugs or medicines or manipulate the environment or diet beyond that easily tolerated by the animal are unacceptable. Experiments resulting in the death of any animal are unacceptable.

Any experimentation involving humans must be with their written permission and must follow the above guidelines. Experiments involving body fluids must not be performed due to the risk of the transmission of blood-borne pathogens.

Internal assessment moderators who see evidence of breaches of the above policy will report the school and a review held.

Academic honesty, Referencing and Bibliography

Academic honesty

From International Baccalaureate Organization (2011). Diploma Programme Academic honesty. International Baccalaureate Organization

Academic honesty must be seen as a set of values and skills that promote personal integrity and good practice. It is influenced and shaped by a variety of factors including peer pressure, culture, parental expectations, role-modelling and taught skills.

Although it is probably easier to explain what constitutes academic dishonesty, such as plagiarism, collusion and cheating, the benefits of properly conducted academic research and a respect for the integrity of individual ideas and products is a key skill within many careers and opportunities.

All IBDP students must understand the basic meaning and significance of concepts that relate to academic honesty, especially intellectual property and authenticity. There are many different forms of intellectual property rights, such as patents, registered designs, trademarks, moral rights and copyright. You should be aware that forms of intellectual and creative expression (for example, published studies) must be respected and are normally protected by law. The school acts in full compliance with all exam boards in tackling plagiarism and further disciplinary action will be taken in line with the school cheating and plagiarism procedures.
Collaboration may be loosely defined as working together on a common aim with shared information, which is an open and cooperative behaviour that does not result in collusion - "allowing one's work to be copied or submitted for assessment by another".

An authentic piece of work is one that is based on your individual and original ideas with the ideas and work of others fully acknowledged. Therefore, all assignments for assessment, regardless of their format, must wholly and authentically use that candidate's own language, expression and ideas.

Where the ideas or work of another person are represented within your work, whether in the form of direct quotation or paraphrase, the source(s) of those ideas or the work must be fully and appropriately acknowledged.

When using the words of another person it must become habitual practice to use quotation marks, indentation or some other accepted means of indicating that the wording is not their own. Furthermore, the source of the quotation (or paraphrased text) must be clearly identified along with the quotation and not reside in the bibliography alone. Using the words and ideas of another person to support one's arguments is a fundamental part of any academic endeavour, and how to integrate these words and ideas with one's own is an important skill that must be taught. Paraphrasing is a skill so that you do not simply copy a passage, substitute a few words with your own and then regard this as your own authentic work.

Referencing and Bibilography

From International Baccalaureate Organization (2014), The IB programme continuum of international education Effective citing and referencing, International Baccalaureate Organization

A style guide is a published manual that gives guidance on citation and references to help ensure that our documentation is expressed consistently, and that we include all the elements needed for our sources to be identified.
Some style guides offer more than one set of choices or sub-styles; if we use a particular sub-style, we must be sure to use the same sub-style throughout our work.
As well as advice on citations and referencing, many published style guides give advice on spelling, abbreviations, punctuation, and so on. Many also give guidance on research and on the general writing process.
Style guides in common use in the academic world include the following.

- MLA (Modern Language Association)
- APA (American Pyschological Association)
- Harvard
- Chicago/Turabian
- CSE (Council of Science Editors)
- ISO 690 (International Organization for Standardization)

Use https://www.citethisforme.com/ to easily create references and bibliographies.

Citation

A citation is an indication (signal) in the text that this (material) is not ours; we have "borrowed" it (as a direct quote, paraphrase or summary) from someone or somewhere else. The citation in the text can be:

- In the form of an introductory phrase, or
- At the end of the statement, or
- Indicated by a superscript or bracketed number that leads to a similarly numbered footnote or endnote.

Every citation should be given a full reference that enables the reader to locate the exact source used.

Reference

A reference gives full details of the source cited in the work; the parts or elements of the reference should be noted in a consistent order. Use of a recognized style guide will help ensure consistency, and will also ensure that all required elements are included.

Every reference should be given a citation in the text. If we have looked at a source but not mentioned or cited it in the text, then we do not include it as a reference.

Bibliography/references/works cited

Most style guides require a list of references at the end of the work. This is usually a list, in alphabetical order, of the authors (last name first), whose words and works have been cited in the work. The title of this section varies from one style guide to another.

Each entry in the list of references includes the full information (or as much of it as can be found), expressed in a consistent fashion, which will allow an interested reader to track down exactly where you found the material you have used and cited.

Paraphrase

In writing an essay, we often use our own words to put over someone else's thoughts and ideas. While there are some words that we cannot change (especially the names of people, places, chemicals, and so on), we should use our own words for as much as we can of the rest of the passage. We should also aim to change the structure of the passage, perhaps by reordering the thoughts and ideas.

When we paraphrase, we need to make it very clear where the original author's ideas start and where they finish. If we include our own examples, we should make it clear that these are our thoughts and not those of the original author.

Summary

A summary is a much-shortened summing up of someone else's work. We might summarize a chapter or academic paper, or perhaps even a book, in two or three sentences. Again, although we are using our own words, we must still cite the original source used.

Summaries are often used in a review of the literature—when we sum up what other writers have said or done in investigating a topic or theme.

Quotation

When we use someone else's exact words, we quote that original author, and we show this is a quotation by using quotation marks. Longer quotations may be indicated by the use of an indented paragraph (without quotation marks). As well as indicating the words quoted, we must also acknowledge the author by using an in-text citation, the citation in turn linking to a full reference.

Quotations should normally be used sparingly and carefully; essays on literary subjects or from historical documents might include more quotations than other essays.