**How to write a GREAT Student Experiment (IA2)**

Disclaimer – This work is the opinion of a teacher and is not supported or recommended in any way by the QCAA. This means the information below is arguable, and you are welcome to engage in discussion with your own teacher and peers regarding the advantages and disadvantages of this information. The information provided below will be greatest assistance to pragmatic students; those focused on getting a good mark as opposed to revolutionising the world of science with your ideas. From a teacher point of view, the student experiment is not given sufficient class time within the syllabus (10 hours) to allow for an in-depth or innovative science investigation and report. There are exceptions to this, however this guide is written to provide most assistance to students who care as much about their grade as they do about their science.

Writing a student experiment report should not be a difficult task. The hard parts (there are only two) actually occur before you write your report, and these are:

**1.** Identifying a suitable experiment to modify, getting the experiment to work quickly, and generating sufficient data. You have only ten hours of class time allocated to the student experiment – do not waste most of this by doing long, extensive repetitions of trials. Pick a simple experiment that will enable you to get results quite quickly.

**2.** Know why you are doing the experiment. This sounds obvious, but many students focus only on what to do, not why they are doing it. You really need to understand the fundamental ideas behind your experiment and have a very clear picture of the aim of your investigation - this makes it much easier to write your report.

Before you start - If you want to get a great mark for your student experiment, then I recommend you follow a specific format for your report. The reasons for this are directly related to how your teacher will mark your report (using the ISMG). The ISMG is quite specific about how your work is graded. In order to make it obvious that your work matches the criteria, I recommend that you structure your report in the exactly same order of the criteria in the ISMG. This will make it easier for the teacher to match your work to each criteria. Avoid making your teacher search the entire report to find where you have met certain criteria… make it obvious. The structure I suggest below follows the criteria closely – and some sections are specifically designed to follow the structure of the criteria closely.

The table below is organised into columns. The left column contains guidance on what structure to use, what heading to use, and tips on how to meet the criteria. The right column lists the criteria that will be used to evaluate your work, and an explaination of the cognitive verb(s) within the criteria. When writing your report I recommend that you do the things in the left column, while thinking about the things in the right column.

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| **Report section - What you need to do** | **Criteria and explanation**  |
| Use a concise version of your research question as your **title**. | No marks for this |
| **Rationale** A considered rational should do **three** key things in about 300 words or less. Parts 2 and 3 are often switched around or combined.**1.** Provide the context for the investigation. Introduce the topic covered by the experiment and positions the topic is in a “big picture” sense. It should describe some of the real life implications of the topic.**2.** Introduce and explain key points of the theory you will use in your investigation. Describe the science within the topic that is relevant to this experiment. Detail any scientific laws or mathematical formulas that apply to the experiment.**3.** Briefly outline the aim of your experiment and explain how your experiment relates to previous research and how your results may contribute to existing knowledge or research. | **One criteria (out of five** for Research and Planning = 6 marks)* *a considered rationale for the experiment*
* *a reasonable rationale for the experiment*
* *a vague or irrelevant rationale for the experiment*
* *does not satisfy any of the descriptors above*

**Cognitive verb explained***Considered* **-** The theory and current research behind the investigation should be evident and clear. Has reference to research and/or data that is directly relevant to the purpose of doing the experiment. The impact of your investigation is explained in the context of previous research or real world implications. |
| **Research Question** State your research question.* One sentence.
* Short and sharp.
* Relate the independent to dependent variable.
 | **One criteria (out of five** for Research and Planning = 6 marks)* a *specific and relevant research question*
* *a relevant research question*
* *an inappropriate research question*
* *does not satisfy any of the descriptors above*

**Cognitive verb explained***Specific* and *relevant* - A precise description of the relationship being investigated which contains clearly defined independent and dependent variables. The research question obviously relates to the topic discussed in the rationale. |
| **Modifications to Methodology**State the experiment you are going to modify (reference it). Then, very briefly describe the method you are going to modify (the original experiment). This is not assessed by any criteria (no marks for it), so do not waste precious words, but it should be useful in providing some context for the teacher to understand your modifications explained below. Do not list your method – there are no criteria or grade for this. There are no marks for using a labelled diagram (although see communication criteria), but you could do this if it makes explaining your modifications easier.Introduce and then list the modifications you made to the method described in your first paragraph. * Use bullet points rather than numbers, as there is no “order” in the modifications.
* Describe accurately, and justify every change to the original method. Justify means to provide the reasons, so the teacher understands why you are varying the original method (check out the right column for more detail on this).
* Modifications are generally things you are choosing to do, however sometimes a modification may be forced upon you because of the equipment you have available (which may be limited). This may mean a modification is not really an “improvement”. Be honest about this in your report – that is life!
* One of the criteria lists the collection of *sufficient* and *relevant* data. It should be obvious to the teacher if the data you are planning to collect is *relevant* to your research question, but the *sufficient* part may not be obvious to your teacher. In your descriptions or justifications, you must make it clear how you intend to collect “*sufficient*” data. There is no clear-cut rule on this, but many would agree that (at least) five data points are needed (to draw conclusions about trends and relationships), and three trials of each data point is a minimum. Your teacher will have an opinion on what is sufficient data is, so ask!

At the very end, I recommend you list the independent variable, the dependant variable, and all of the controlled variables. There is no mark for doing this, but it will be useful when discussing limitations of the data later in the report. | **Two criteria (out of five** for Research and Planning = 6 marks)**Modification to Methodology*** *Justified modifications to the methodology*
* *feasible modifications to the methodology*
* *inappropriate modifications to the methodology*
* *does not satisfy any of the descriptors above*

**Cognitive verb explained***Justified* – Provide valid reasons for the modifications to the methodology in terms of (one of the following)* refining (improving) previous investigations by improving accuracy or range of data, and/or
* extending or redirecting (increasing the range of, and/or
* changing or adding independent variable) previous investigations, and/or
* confirming theoretical models of previous investigations.

**Methodology allowing for the collection of data*** *a methodology that enables the collection of sufficient, relevant data*
* *a methodology that enables the collection of relevant data*
* *a methodology that causes the collection of insufficient and irrelevant data*
* *does not satisfy any of the descriptors above*
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| **Risk management**There is a variety of ways to do this and your teacher is the best person to ask as to what they may consider an appropriate way to describe the risk associated with your experiment.One simple way is to use the following table (put in a table heading):

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| Source of risk | What degree of harm? | Safety precautions taken | If incident occurs, procedures to follow |
|  | Major / minor / significant |  |  |
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If you are using this table, make sure to:* be accurate but concise with your description of “source of risk”
* list the most severe “degree of harm” possible
* use the basic prescribed precautions used in a lab and add any specific precautions you may have added. Be basic here, but thorough.
* Be realistic – for example, you do not have to write about tripping over, unless of course your experiment involves using equipment that creates specific tripping hazards.
 | **One criteria (the last criteria out of five** for Research and Planning = 6 marks)**Risk Management*** *considered management of risks and ethical or environmental issues*
* *management of risks and ethical or environmental issues*
* *inadequate management of risks and ethical or environmental issues*
* *does not satisfy any of the descriptors above*

**Cognitive verb explained***Considered* - All reasonable sources of risk are identified, and realistic and appropriate safety precautions are detailed.  |
| **This is the end of the Research and Planning criteria (6 marks). Starting the four criteria for Analysis of Evidence (6 marks).** |
| **Results – Raw Data**Present your raw data first. Note that there may not appear to be obvious marks in this section for the presentation of your data. However, the criteria “processing of data” (see next page) does include the *visual and graphical representations of data* (look at the ISMG for this detail). Your teacher is also likely to consider your presentation of data as part of your communication criteria (see the end), so it worth setting out the tables and graph correctly.* + A table will have a numbered heading such *Table 2:* “*this will be a description of the data”*
	+ The first column will be your independent variable, so the heading in this column will be your independent variable (along with units)
	+ The second Column will be your dependent variable, so the heading will be your dependent variable (along with units).
	+ You may need to split your second column - assuming you are doing more than one trial and averaging (RECOMMENDED! you do this)
	+ Additional columns may be needed if other measurements were taken.
	+ Your table should have at least 5 rows to collect 5 variations of your independent variable
 | **One criteria (out of four** for Analysis of Evidence = 6 marks)**Collection of raw data*** *collection of sufficient and relevant raw data*
* *collection of relevant raw data*
* *collection of insufficient and irrelevant raw data*
* *does not satisfy any of the descriptors above*

**Cognitive verb explained**See earlier criteria for these cognitive verbs |
| **Results – Processing the Data**This is a lot of work here for one criteria. Three main partsWe recommend you start (the first part) with a simple identification of anomalies in the raw data. For example you may identify one of the trial values as being significant different to the other two, and therefore may choose to not use this value in the calculation of your average. Here you simply identify each anomaly and the reason you are not using it. The second part provides an example of all the calculations you do to your raw data in order to create secondary data. It will also show all the uncertainty associated with each calculation. I recommend you use a table with two columns – an example of each calculation in the left column, and the calculation of uncertainty in the right column. Setting it out this way allows your teacher to check that you have done all the correct uncertainty calculations.Technically this criterion also covers the presentation of your primary and secondary data, which should be in a table and on a scatter plot with a trend line. This third part should be a table of secondary data and the graphical representation of it. The graph should have uncertainty bars (people call them error bars, but they are not error) for each data point, a trend line with R2 value and equation for the trend line. | **One criteria (out of four** for Analysis of Evidence = 6 marks)**Processing Data*** *correct and relevant processing of data*
* *basic processing of data*
* *by incorrect or irrelevant processing of data*
* *does not satisfy any of the descriptors above*

**Cognitive verb explained***Correct and relevant*– this includes the appropriate presentation (scientific genre) of all relevant scientific data and processes involved in converting primary (raw) data into secondary data. This includes the correct application of algorithms involved in calculating secondary data, uncertainty, percentage error (where appropriate), and correct use of significant figures. Secondary data is graphically represented where appropriate, and graphical processes are applied appropriately to the data (trend lines, error bars, equations, R2). |
| **Analysis of trends and relationships**This section is quite simple but it sets up your conclusion section, so spend some time on it. Here is where each trend or relationship in your data is identified - key word is “identified”, you do this by:* Providing a description of each trend.
* Quoting data to elaborate your description.
* Refining the description to be as exact as possible. This usually means describing the trend with a mathematical equation. If the trend is unusual and a math equation is not useful, then describe the trend in more detail.

The other key word is “thorough”. Teachers will use two basic rules to asses thorough in marking this section… * if the teacher can see a pattern in your raw data or secondary data and you have not identified it, you have not been thorough
* If you have not quoted data to support your identification of a trend, and not used an appropriate math equation (or supplied additional detail to describe a complex trend); then you have not been thorough.

The most obvious trends/relationships will be the ones evident in your secondary data, especially the relationship between your independent variable and your dependant variable. However, there may be other minor trends evident in the raw data table – trends that relate to patterns of uncertainty or variation in the trials. Start with the most important trend first, then descending order of importance. | **One criteria (out of four** for Analysis of Evidence = 6 marks)**Analysis of trends and relationships*** *thorough identification of relevant trends, patterns or relationships*
* *identification of obvious trends, patterns or relationships*
* *identification of incorrect or irrelevant trends, patterns or relationships*
* *does not satisfy any of the descriptors above*

**Cognitive verb explained***Thorough identification*– All relevant trends and patterns evident in the data are described in detail and the description is supported by appropriate use of the data. Any relationship between two variables is defined as a mathematical equation and supported by appropriate use of data. |

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| **Analysis of data uncertainty and limitations** There is only one criteria for this section, but spend some extra time here as some of the uncertainty and limitations you identify will be referred to later, when you evaluate data reliability and validity. This section identifies the uncertainty within the data and the limitations of the data – you must identify both. I recommend you do them one at a time to keep things simple. Before you start, make sure you are aware of the difference between uncertainty and error. In this section, you are discussing uncertainty, not necessarily error. There are several ways to discuss uncertainty and these are outlined below. You should **definitely** describe the significance of the uncertainty you calculated earlier (in Results – processing the data). This is highly subjective as some uncertainty values may be high because of equipment or techniques you used, and you will need to think carefully when describing how uncertain your data is. I cannot offer much general guidance here; however, the uncertainty calculation is not the only way of measuring uncertainty. There are other methods to measure uncertainty; and you can use these to identify uncertainty. * You will have done trials in your experiment. Have you identified many anomalies within the trial data? If all the results for the trials were close to each other, this would indicate low uncertainty in your results. If you identified several anomalies, you probably did not use these anomalies in your uncertainty calculations. However, the fact that these anomalies exist in your raw data indicates there is possibly greater uncertainty than you calculated.
* You probably have a scatter plot with a trend line. Ask yourself the question…do the points on your graph make a consistent trend (are the points close to the trend line or a little “scattered”?). The closer the points are to the trend line the less uncertainty you have in your trend or relationship. See sidenote about R2.
* Does you trend line fall with the range of the uncertainty bars on the scatter plot? If your trend line lies outside some of the uncertainty bars, there is additional uncertainty within your trend or relationship (not the data, just the trend).

The cause of the uncertainty should be listed and briefly described in terms of random or systemic error within the methodology. When discussing **limitations** of your data, the most obvious discussion should be concerning the scope and scale of your data. Is there sufficient variation and sufficient range in the independent variable? Like uncertainty this can be a difficult decision, so think carefully before you identify the limits of your data. Some ways to assess limitations are:* Are there enough data samples to describe the trend accurately (scope)?
* Is there sufficient variation within your independent variable (scope)? If there is not enough variation, the trend you identified may not be real (valid).
* How well were the controlled variables (scope and/or scale) actually controlled? Uncontrolled variables contributes to both uncertainty and limitations of the data, but any numerical uncertainty it created would have been discussed above. Here you need to identify and evaluate if being unable to control all the controlled variables limits the scope or scale of the conclusions. Big hint… it obviously affects the scope or the scale of the data, but by how much is the bit you have to identify.
* Are the values of your independent variable an exact match for the scope of the research question (scale)? If your independent variable values are too far from the research question then you will have to extrapolate from your results to results that suit the research question. The most common example is where you set up your experiment to be completed quickly rather than the several months it should be done in. This means your values for the independent variable may be quite different from those implied in the research question.
 | **One criteria (last one out of four** for Analysis of Evidence criteria = 6 marks)**Data uncertainty and limitations*** *thorough and appropriate identification of the uncertainty and limitations of evidence*
* *basic identification of uncertainty and limitations of evidence*
* *incorrect or insufficient identification of uncertainty and limitations of evidence*
* *does not satisfy any of the descriptors above*

**Cognitive verb explained***Thorough* and *appropriate* – the degree of **uncertainty** in the results is discussed in relation to the precision (calculated uncertainty) of the secondary data. Uncertainty should also be identified through qualitative evaluation of trials and data variation. The cause of the uncertainty should be identified and categorised as random or systemic. **Limitations** of the data is discussed in terms of the scope and scale of the data. Scope refers to whether the variation of the independent variable in the experiment is the same as that implied in the research question. Scale refers more to whether the is sufficient variation to produce a meaningful (valid) trend line, and whether uncontrolled variables affected the results so much that the stated variation of the independent variable are not valid representations (your trends are not valid).**Sidenote:** Many students use the R2 value (provided by an excel plot) to measure the certainty within the trend. However, be careful using R2 as it is NOT actually a measure of (un)certainty or error within your data. If you are going to quote or reference an R2 value, make sure you know what it means and use it appropriately (Jim frost has written a very good article on R2 - see <https://statisticsbyjim.com/regression/interpret-r-squared-regression/>).**While I’m here…** since I mention them, here isa brief explaination of scope and scale**Scope –** whether your experiment measured what it was intended to measure.**Scale** **-** whether your experiment accurately reflects your research question. |
| **This is the end of the Analysis of Evidence criteria (6 marks). Starting the three criteria for Interpretation and Evaluation (6 marks).** |
| **Conclusion**The first sentence should be a statement identifying the relationship between your independent variable and your dependent variable. You can quote the mathematical relationship you have determined if you have one. If you do not have a “relationship”, you should state your main finding. Use data from support your description of the relationship or main finding. Explain the implications of this relationship on your research question. Be obvious about this latter part. The criteria (on the right) distinguishes between linked (better) and relevant (okay). Most teachers will interpret this as being either directly and obviously relevant, versus obliquely and somewhat relevant. So think about how to make the connection between your conclusion and your research question direct and obvious. You may need two paragraphs to cover all this.If you can make another conclusion, start another paragraph and do the same thing.  | **One criteria (out of three** for Interpretation and Evaluation = 6 marks)**Conclusion about research Q*** justified conclusion/s *linked* to the research question
* reasonable conclusion/s relevant to the research question
* inappropriate or irrelevant conclusion
* does not satisfy any of the descriptors above

**Cognitive verb explained***Justified* – Provide valid reasons for the conclusion(s) through appropriate use of data and logic reasoning; and describes meaningful implication of the conclusion which are directly relevant to the research question |
| **Evaluation of reliability and validity**In the OP system, this part of the conclusion used to be the error discussion. It is still about error, but the criteria are very specific about what you must do. Your discussion of error must centre on the idea of reliability and validity. The criteria uses the term “experimental process” as a reference to all parts of your experiment (from the wording of the research question through to the conclusion). This means that although your discussion about reliability and validity is likely to be mainly about your data and conclusions, you can discuss all parts of the experiment.You can discuss the reliability and the validity of the data/conclusion together, but most people find it easier to discuss them separately. Reliability generally refers to whether your data is repeatable. The uncertainty in your results is an excellent guide to reliability, so I recommend you use the calculated uncertainty to justify the reliability of your data. There were other ways to evaluate uncertainty however (covered earlier in the Analysis of data uncertainty and limitations) so also use these in your justification of reliability. Validity generally refers whether your experiment measured what you intended it to measure and/or whether your experiment accurately reflects your research question. The arguments you will use to justify validity should be drawn from your discussion of the limitations of your data (also covered earlier in the Analysis of data uncertainty and limitations). If your data is limited in scope or scale, then your conclusion is not valid. Another way of evaluating validity is by identifying the error in your result/data. Error can only be determined by comparison of your result/data/conclusion with a known or text value. If your result matches existing theory or a known result, then this can be used to justify validity.  | **One criteria (out of three** for Interpretation and Evaluation = 6 marks)**Evaluation of reliability and validity*** justified discussion of the **reliability** and **validity** of the experimental process
* reasonable description of the **reliability** and **validity** of the experimental process
* cursory or simplistic statements about the **reliability** and **validity** of the experimental process
* does not satisfy any of the descriptors above

**Cognitive verb explained***Justified* – Uses evidence from within the report to provide valid and logical reasons in the evaluation of the reliability and the validity of the conclusion(s).**Reliability** is the likelihood that another experimenter will obtain the same results (or very similar results) if they perform exactly the same experiment under the same conditions. This is related most obviously, but not exclusively, to uncertainty.**Validity** is the extent to which tests measure what was intended. It is related to the limitations and the error in the data. |

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| **Improvements and Extensions**You must suggest both improvements and extensions, although you may have only one of each. Like the last section, you can discuss improvements and recommendations together or separately. I recommend separately only because it is easier. Improvements are generally things that already exist within your methodology, but you think should be changed. It should be quite easy to identify several improvements and your discussion of uncertainty and (possibly) limitations will help you with identifying improvements. Any improvement you suggest should be “*logically derived*” from the analysis of data. Be obvious about this. Each improvement you suggest must be explained by discussing a deficiency within the primary or secondary data. Extensions are changes you should make to things that are not within the scope of your existing methodology. In other words, now that you have done this experiment, what should be done next? You may recommend an extension because your data did not cover the entirety of your research question. The discussion about limitations earlier in your report should guide you towards such an extension to the experiment. Alternatively, because of doing this experiment, you may have identified another research question that should be investigated. Any extension you suggest should be “*logically derived*” from the analysis of data. Be obvious about this. Each extension you suggest must be explained in terms of its connection to the data you collected in this experiment. | **One criteria (last one out of three** for Interpretation and Evaluation = 6 marks)**Recommendations*** *suggested improvements and extensions to the experiment that are logically derived from the analysis of evidence*
* *suggested improvements and extensions to the experiment that are related to the analysis of evidence*
* *ineffective or irrelevant suggestions*
* *does not satisfy any of the descriptors above*

**Cognitive verb explained***Improvements* - modifications to an investigation that mitigate the limitations of the evidence, method or design.*Extensions* - modifications to an investigation that could be used to further examine a claim.*Logically derive* - arrive at by clear, sound reasoning.  |
| **This is the end of the Interpretation and Evaluation criteria (6 marks). Starting the three criteria for Communication (2 marks).** |
| The three criteria for communication (listed on the right) are evaluated holistically, across your entire report. Your teacher is your best guide for how to meet these criteria.Some general guidelines:* Be concise, and accurate with the use of scientific terms.
* Use a passive voice (emphasises the action not the subject) and no personal pronouns.
* Use past or present tense (past tense is traditional but both are now considered generally acceptable), but do not mix tense.
* Use appropriate labelling and title for tables and graphs.
* Use in text referencing and a well-accepted reference system (such as Harvard - your school will have a recommendation).
 | **Communication** (throughout document)* + fluent and concise use of scientific language and representations
	+ competent use of scientific language and representations
	+ does not satisfy any of the descriptors above.

**Genre** (throughout document)* + appropriate use of genre conventions
	+ use of basic genre conventions
	+ does not satisfy any of the descriptors above.

**Referencing** (throughout document)* + acknowledgment of sources of information through appropriate use of referencing conventions.
	+ use of basic referencing conventions.
	+ does not satisfy any of the descriptors above.
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When you have finished – Two things

**1.** Go back and rewrite some parts using the words within the criteria. This is another way of being obvious that you are matching the criteria. If you are discussing data reliability (Evaluation of reliability and validity) but do not use the words data and reliability, your teacher has to make the link themselves in order to give you credit. Your teacher is smart and can do this, but why not make it obvious.

**2.** You have a word limit of between 1500 and 2000 words. It is very unlikely your teacher is going to count the number of words you write, however if your report goes on and on and is obviously too long, your teacher is obligated to stop reading beyond a reasonable 2000 words estimate. You will not receive marks for work beyond this point. Be mindful of this in your drafting process. 2000 words is plenty and your report should easily be below this, but if you are typically verbose, rein it in during the drafting process - ensure you are obviously within the 2000 word upper limit.