**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 advice given below. My belief is that this advice 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. This guide is written to provide most assistance to students who want to achieve very highly.

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 criterion. 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.

Word count is a real thing! Keep two word counts. One is the total word count, the other is word count with exclusions (see later what these are).

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| **Report section - What you need to do** | **Criteria and explanation** |
| **Title** - Use a concise version of your research question. | No marks – keep it simple don’t waste time. |
| Research and Planning Section (6 marks) – 5 criteria.   * the rationale is the most work here (by a fair margin) but is the same value as other criteria. * two criteria for your modifications to the method – maximum value for effort here, take some time to ensure you get these criteria. | |
| **Rationale**   * A considered rational should do three key things in about 300 words or less. * Paragraphs 2 and 3 are often switched around/combined.   First para - 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.  Second para - Introduce and explain key points of the theory you will use in your investigation. Essentially this is describing the science relevant to this experiment. introduce and describe any scientific laws or mathematical formulas that apply to the experiment.  Third para - describe the aim of your experiment as your topic sentence. Then explain how your experiment relates to previous theory or research you have found. If you can describe how your results may contribute to existing knowledge or research. | * *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 context (1st para) is always relevant, clearly explained, included facts are supported by references. There is nothing missing, but also no irrelevant detail. * All of the theory and/or current research needed to understand the results (2nd para) should be described clearly, and supported by referencing (multiple sources preferred). * You have clearly described how your experiment adds to or complements existing theory, or previous research, or what its real world implications are (3rd para). You only need one of these three options. |
| **Research Question** State your research question.   * One sentence. * Short and sharp. * Relate the independent to dependent variable. * Include any variation details (such as concentration range of one variable etc) | 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*, *relevant.* Relevant should be a given if you have done a rationale. Specific means be precise in describing your independent and dependent variables. It should be a question which can be answered with a relationship, not a yes/no answer. |
| **Modifications to Methodology**   * Do not list your method as there are no criteria or grade for this.   First para - name the original experiment you are going to modify (reference it). Then, very briefly, in one or two sentences, describe the findings of the original experiment you are going to modify. No marks for this (do not waste precious words) but it should be helpful to the teacher in understanding the modifications you make.   * 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. * After you have described the original experiment (or at least named it), 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. * Modifications are either an “extension” to the original experiment, or a “refinement” of it. Use these terms - if used correctly you will sound smarter! * Describe each modification accurately, and after each description follow with a justification. Justify in this case simply means to provide the reasons, so the teacher understands why you are varying the original method (check out the right column, where the cognitive verb justified is explained, 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. Make sure that somewhere in your descriptions or justifications, you make it clear how you intend to collect “*sufficient*” data. You MUST do this twice, see the right column for advice on how to do this simply.   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 may be useful when discussing limitations of the data later in the report. Delete it later if not useful. | * *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 (at least one of)   * refining (improving) previous investigations by improving accuracy or range of data; * extending previous investigation by measuring a different dependant variable; * extending previous investigation by changing or adding independent variable); * confirming theoretical models of previous investigations (not really recommended as this is not likely to require significant modification).   **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*   **Cognitive verb explained -** *Sufficient*  There is no clear-cut rule on this, but many would agree that at least   * 5 variations of your independent variable) are sufficient to identify trends and relationships accurately from the data. * 3 trials of each variation of the independent variable is sufficient to reduce the random uncertainty in the data.   Your teacher will have an opinion on what is sufficient data is, so ask! |
| **Risk management**   * One simple way is to use the following table (put in a table heading):  |  |  |  |  | | --- | --- | --- | --- | | Source of risk | What is the possible degree of harm? | Safety precautions taken | If incident occurs, procedures to follow | |  | Major / minor / significant |  |  | |  |  |  |  | |  |  |  |  |   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. * Use the riskassess.com site to inform you of certain risks, but there is no need to include their safety forms (check with your teacher though) * Use a subheading Environmental Issues. You must address ethical and/or enviro issues. Here you should discuss the potential effect on the environment of your use/disposal of chemicals and how you will mitigate these effects. | * *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. Both accident risk and ethical/environmental need to be done  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. |
| Analysis of Evidence (6 marks) - four criteria | |
| **Results – Raw Data**   * Check with your teacher, but I recommend presenting your raw data first as there is a criterion which relates to raw data. Alternatively, if you have a very large amount of raw data, put it in an appendix, but include a small summary table in the body of your report. * Be careful and precise setting out the tables and graph correctly. There is not “obvious” mark for presentation, but poor structure in tables can hurt you in two criteria. One is “correct processing of data” (in this section), and the other is in communication, which has a criterion of scientific genre.   There are some basic rules for setting out tables but you should know them by now – check with your teacher is not sure. | **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 –** *Sufficient, relevant*  Assuming your data is relevant, you must show you have collected sufficient data. This means at least five rows (five variations of independent variable), and multiple columns of trials, along with a column of an average. Other data which is relevant must also be included either in the table or as footnotes to the table. |
| **Results – Processing the Data**   * This is a lot of work here for one criteria. * First, start by labelling and justifying any anomalies in the raw data. Label in the raw data with an asterisk, and justify in a footnote to your raw data table. * Secondly, provide an example of all the calculations you did to your raw data in order to create the secondary data. Alongside each example calculation you need to show how uncertainty was propagated 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. Start the table by identifying which data point you are going to use as your example. * Thirdly, present a table of secondary data, and the graphical representation of it. The graph should ideally be a scatter plot with a trend line. Any graph should have uncertainty bars for each data point (most people call them error bars, but they show uncertainty, not error), a trend line, and a R2 value and equation for the trend line. | * *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**  *Relevant*– this includes the appropriate presentation (scientific genre) of all relevant scientific data and processes involved in converting primary (raw) data into secondary data. Secondary data is graphically represented appropriately, and graphical processes are applied appropriately to the data (trend lines, error bars, equations, R2).  *Correct -* This includes correct identification of anomalies; the correct application of algorithms involved in calculating secondary data, uncertainty, and percentage error (where appropriate); and correct use of significant figures. |
| **Analysis of trends and relationships**   * This section is quite simple but it sets up your conclusions, so spend some time on it. * I am assuming you understand the term “relevant trends, patterns or relationships” means only discuss trends which has meaning to your research Q. Don’t just identify every trend. * Write a para for each trend and follow the same arguments for each para (see below). * Identify means do exactly that, and start very simply. You can interpret, but be careful as you are marked on identifying, not concluding for this section. You identify by: * Starting each para with a description of the trend. This means identifying what change occurs in the dependant variable as the independent variable either increases or decreases. * Second, quote some data (not all of it) to support your description. * Thirdly, be more precise in the description of the trend. This usually means describing the trend as linear or curved, and with a mathematical equation. If the trend is unusual and a math equation is not useful, then describe the trend in more detail. * 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 are relevant to uncertainty in the data. Start with the most important trend first, then identify in descending order of importance. | * *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*   Assuming you have followed the format described on the left you should be okay with the “identification” part of this criteria. Any conclusion you have made will be ignored by your teacher, so you need to have clearly identified the trends. This leaves…  **Cognitive verb explained** - *Thorough*  All relevant trends and patterns evident in the data are described in detail and the description is supported by appropriate use of the data. Your teachers is likely to use two basic rules to assess thorough in marking this section…   * if the teacher can see a pattern in your raw data or secondary data (which is relevant to your RQ, or the reliability of your 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. |
| **Analysis of data uncertainty and limitations**   * There is only one criterion for this section, but spend some extra time here as some of the uncertainty and limitations you identify will be used later, in the evaluation section. * You must discuss both uncertainty and limitations, but they are very different, so discuss them separately. * Before you start, make sure you are aware of the difference between uncertainty and error. In this section, you are discussing uncertainty (precision), not necessarily error (accuracy).   Uncertainty - there are several ways to discuss uncertainty and these are outlined below.   * You should definitely describe the significance of the uncertainty value you calculated earlier. A high percentage uncertainty indicates you cannot be certain about the precision of the data, and therefore your identification of the trend (and any conclusions drawn from it) lack certainty. It does not mean your trend is wrong (that is error). * You will have done trials in your experiment. Have you identified many anomalies within the trial data? If all the trials were close to each other, this would indicate low uncertainty in your results. If you have anomalies, you did not use these anomalies in your uncertainty calculations. So you may have low calculated uncertainty, but 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. Do the points on your graph make a consistent trend (are the points close to the trend line or a little “scattered”?). The more scattered the points are the more uncertainty you have in your trend or relationship. See sidenote about R2. * Does the 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 itself, just the trend). * The cause of the uncertainty should be listed and briefly described in terms of random or systemic error within the methodology.   Limitations – most students don’t fully understand what limitations are. In terms of limitations you are asking if your data does two things. Firstly, does it actually measure what you were intending it to measure? Secondly, does it accurately reflect your RQ? Discussing limitations of the data can be difficult, so some ways to assess limitations are:   * Is there enough variation within your independent variable? Two ways this can happen. You do not have at least 5 variations of the independent variable. This limits your ability to determine a trend. Alternatively, your range of variation may to too small and the trend you identified may only be correct for this small range of the independent variable, but not other values of it. This limits your ability to make conclusions * Are the values of your independent variable an exact match for the RQ? If your independent variable values are too far from the real-life context of the RQ then you will have to extrapolate from your results to results that suit the research question. Commonly this happens because you set up your experiment to be completed quickly – and your values for the independent variable may be quite different from those implied in the RQ. This limits your ability to use the conclusions to answer the RQ. * How well were the controlled variables actually controlled? Uncontrolled variables mean there may have been other influencing variables other than your independent variable. In other words, your trend may have been caused by things other than your independent variable. This limits your ability to make conclusions. | * *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* – **uncertainty**  Uncertaintyin the results is discussed in relation to   * the quantitative (calculated uncertainty) precision of the secondary data. * the qualitative evaluation of trial anomalies * the qualitative evaluation data variation on the graph. * The cause of the uncertainty should be identified and categorised as random or systemic.   **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. Is more a measure of how well your data points fit your regression model (the trend line) – so it can help you identify which trend line best describes your data. It is more complicated than this, and low R2 values are not all bad. 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 this article](https://statisticsbyjim.com/regression/interpret-r-squared-regression/)  **Cognitive verb explained**  *Thorough* and *appropriate* – **limitations**  limitationsin the results are discussed in relation to   * the variation (number of, and range of) of the independent variable. * A comparison of variation of the independent variable with the implied variation in the RQ * Whether uncontrolled variables were able to influence the results so much that the trends identified may be caused by the variations in the independent variable. |
| Interpretation and Evaluation (6 marks) – three criteria | |
| **Conclusion**   * There should only be one or two paras in your conclusion. Generally speaking one para per conclusion. * Each para should have a topic sentence that is the actual conclusion and be relatively short (unless your results or RQ is very complex)   Firstly - The paragraph should start with a conclusion relating your independent variable, your dependent variable, and your RQ. This is your main conclusion (not a trend). If it does not directly answer your RQ write another sentence elaborating the topic sentence. Your conclusion has to be *linked* directly to the RQ(see the criteria), so make your conclusion an obvious answer to the RQ  Secondly – Support this conclusion with the trend(s) you identified. Follow this with a description of the mathematical relationship you have determined if you have one. If you do not have a “relationship”, you should state your main finding. This relates to the *justifying* part of the criteria.  Thirdly - Explain the real-world implications of this relationship. Be obvious about this as it helps the teacher with the *linked* part of the criteria. However some experimental results do not have real life implications.  If you can make another conclusion, start another paragraph and do the same thing. | * 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*  In the context of justifying a conclusion, your teacher will be looking for you to provide valid reasons for the conclusion(s) through logical argument using of data or trends;  **Cognitive verb explained** - *linked*  In this criterion linked is better than relevant, but the differences between these two are not always obvious. Your teacher will most likely look for both of the things below:   * An identification and explanation of the conclusion as an answer to your RQ. Ideally you did this in your first paragraph. * describes meaningful implications of (or predictions from) the conclusions, which directly relate to the research question |
| **Evaluation of reliability and validity**  The criteria are very specific, you discuss how reliable and valid the experimental process has been. You can discuss the reliability and the validity of the data/conclusion together, but most people find it easier to discuss them separately.   * The criterion uses the term “experimental process” … meaning 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 the data, trends, and conclusions, you can discuss all parts of the experiment. * **Reliability** generally refers to your data and whether it is repeatable. The uncertainty in your results is an excellent guide to reliability, so I recommend you use your earlier identifications of uncertainty (covered earlier in the Analysis of data uncertainty and limitations) to justify the reliability of your data. Data and/or trends that are uncertain, and therefore not reliable, indicates that the conclusions you made are also not reliable (remember to say this about the conclusion) * **Validity** generally refers mainly to the trends you identified and conclusions you made. Use the limitations you identified earlier, but here you can also discuss error. There are three reason your trends and conclusions make not be valid (see limitations for detail): * You did not measure what you intended to measure because; not enough variation in the indep variable; did not control the controlled variables * whether your experiment method accurately reflects your research question. * You can identify your result as “wrong” and there is error in your data. Error can only be determined by comparison of your result with a known value. This known value must be referenced, or generated from a theoretical equation which is referenced. | * 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. |
| **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. | * *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 uncertainty and limitations of the evidence, method or design.  *Extensions* - modifications to an investigation that could be used to further examine a claim.  *Logically derive* *from the analysis of evidence* - arrive at by clear, sound reasoning, and obviously connected to the analysis of data. Be very obvious here and connect to your uncertainty and limitations directly, don’t just waffle on with general statements. |
| **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. |

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. This is becoming a big issue in QCAA assessment. Keep a word count, in fact keep two. The first is your word count total, the second is with exclusions removed. Place both of these at the end of your assignment either before of after the references.

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| **Determining word length count of a written response** | | |
| **Inclusions**  • all words in the text of the response  • title, headings and subheadings  • tables, figures, maps and diagrams containing information other than raw or processed data  • quotations  • footnotes and endnotes (unless used for bibliographical purposes) | **Exclusions**  • title pages  • contents pages  • abstract  • bibliography | • reference list  • page numbers  • in-text citations  • raw or processed data in tables, figures and diagrams |