**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 by writing an amazing idea. 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 what you are trying to achieve with 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.

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 explanation 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).

Expert tip: DO NOT WRITE A GREAT REPORT!!!! Instead, write a report which gets a great mark. Unfortunately, a great report and a great mark can be different beasts. The most import thing you need to keep in mind is to meet all the criteria. So, DO NOT simply start writing. Sketch out your structure, write down key points (called a skeleton) for all your sections, understand what you are going to say, make sure each criterion is covered, then start writing. This is what ensures a great mark without having to continually go back over and rewrite your work.

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| **Report section … what you need to do** | **Criteria and explanation**  |
| **Title** - For your title just use a concise version of your research Q. Many of my students put in a contents page. I have absolutely no idea why, as I do not read it… but they still do so! | No marks – keep it simple don’t waste time. |
| **“FORMING” Section (5 marks).*** **5 criteria** – three (the middle three) are very simple to target.
* You can write directly to the first 4 criteria – have headings for them.
* The rationale is the most work here (by a long way) but is the same value as the other criteria.
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| **Rationale** * A considered rational should do three key things in about 300 words or less.

First paragraph - provide the context for the investigation. Introduce the topic covered by the experiment and positions the topic is in a “big picture” sense within an importance to society” context. It should list and/or describe some of the real-life implications of the topic.Second paragraph - Introduce and explain key points of the theory you will use in your investigation. Essentially this is describing the chemistry relevant to this experiment. introduce and describe any scientific laws or mathematical formulas that apply to the experiment. Third paragraph – Paraphrase your RQ 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. | **Criteria***:** ***a considered rationale for the experiment***

“Considered” in a rationale means two things. The first is that you show you understand the significance of the chemistry you are investigating (real world implications). The second is that you show an understanding of all the chemical principles involved in performing and analysis the experiment.* In the first paragraph, the context (significance of the chemistry) must be clearly explained. Included facts to support this context - supported by references. No irrelevant detail.
* In the 2nd paragraph, all of the theory and/or current research needed to understand the results should be described clearly, and supported by referencing (use multiple sources).
* You have to one (as a minimum) of three things clearly described how your experiment:
* adds to or complements existing theory, or
* confirm previous research, or
* has real world implications .
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| **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)
 | **Criteria***:** **a *specific and relevant research question***

“Relevant” should be a given if you have done a rationale. “Specific” means be precise in describing both your independent (including range of your 5 variations) and your 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 paragraph - 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 but you could do this if it makes explaining your modifications easier. Make sure any diagram is 2D, super neat, with clear labelling (this would ensure your genre mark)
* After you have described the original experiment (or at least named it), list the modifications you made. This is easiest in a table format:

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| Modification | Justification |
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 Using a table makes it easy for the teacher to allocate you the mark for having all the correct justificationsJustify 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. This usually means 5 variations of the indep variable, and three trials at each variation. Be obvious about this - see on the right for more detail

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. | **Criteria***:** ***Justified modifications to the methodology***

“Justified” means to provide valid reasons for the modifications to the methodology. A generalised version of modifications are described below - you will likely do all of them, plus some more. You should end with a minimum of four or five modifications. The 3 modifications that all exps will have are:* Changing the independent variable. This is justified by: in order to investigate the relationship between ……….. ;
* using 5 variations of the independent variable (*you may have used more, just make sure you use at least 5*). This is the minimum number of data points required to precisely determine a trend.
* using 3 trials (*you may have used more, just make sure you use at least 3*) at each variations of the indep var. This is the minimum number of trials needed to determine and reduce random uncertainty.

Other modification you may have used:* modifying previous investigation by measuring a different dependant variable;
* refining (improving) previous investigations by using equipment to improve accuracy or range of data;

There is a second criterial marked under the heading **Criteria***:** ***a methodology that enables the collection of sufficient, relevant data***

This is another reason to be obvious about using 5 variations and three trials as explained above. This is generally considered sufficient, but your teacher will have an opinion on what is sufficient data is, so ask! |
| **No Heading**The last criteria for this section involve genre and referencing. This means* 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).
 |  **Criteria***:** ***appropriate use of genre and referencing conventions***
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| **“FINDING” Section (5 marks)** * **3 criteria**
* You write directly to the first 2 criteria – have headings for them.
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| **Risk management*** One simple way to cover risk is to use the following table (but put in a table heading):

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| Source of risk | What is the possible 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”. For example… “acid” is not an acceptable source description. List the most severe “degree of harm” possible for each sourceUse the basic prescribed precautions used in a lab and add any specific precautions you may need. 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) | * *considered management of risks/ethical/environmental issues*

**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 doneThere 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.Cover several Chemical/Physical risks. Also identify any Environmental risk and any Ethical concerns in this table. If these latter two categories do not apply to your experiment, you must say so, and explain, or it looks like you just missed them out and you will lose marks.See the exemplar for some additional guidance re the set out of this table |
| **Results** **Raw Data Table**Present your raw data in a table as there is a criterion which specifically relates to it. 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. There are some basic rules for setting out tables but you should know them by now – check with your teacher if not sure. See the exemplar for a guide to what your tables should look like. | **Collection of raw data*** *collection of sufficient and relevant raw data*

**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. Other data which is relevant must also be included either in the table or as footnotes to the table. Be careful and precise setting out the table. It is likely that your teacher will note any missing units or poorly organised data (out of order, not aligned, etc.) and mark you down under the criteria related to “use of scientific language and representations”. |
| **NO HEADING**This is not a criterion you can write to directly. Your teacher will mark this across the whole of your assignment. The most obvious two things your teacher will be looking for is that your use of chemistry language is correct and that tables and graphs are correctly organised, have correct headings, with units, and “look” very precise | **Criteria*** *fluent and concise use of scientific language and representations*
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| **Analysis of Evidence (5 marks)**- 3 criteria. You write directly to all three of them. |
| **Results** **Processing the Data*** This is a lot of work here for one criterion.
* First, start by labelling and justifying any anomalies in the raw data. Label these in the raw data table 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 three columns
* In the first column, describe the process you are showing;
* In the second column, show the formulas you are using;
* In the last column show the calculation for one of your raw data points. This includes propagating uncertainty in the right column.
* 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, an R2 value, and equation for the trend line.
 | **Criteria*** *correct and relevant processing of data*

Cognitive verb explained*Relevant* – this includes the appropriate presentation (scientific genre) of all scientific data and calculations 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.Check out the exemplar to see an example structure for data processing |
| **Analysis of trends and relationships*** This section is quite simple but done well, it sets up your conclusions.
* The key cognitive verb in the criteria is *Identify.* Do exactly that. You can interpret or propose implications, but be careful as you are marked on identifying, not concluding for this section.
* 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 any trend.
* Write a paragraph for each trend and follow the same arguments for each paragraph (see below).
* You identify by:
* Starting each paragraph 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, trends relating to the relationship between your independent variable and your dependant variable. However, there may be other minor trends evident in the raw data table – trends relating to the uncertainty in the data. Start with the most important trend first, then identify in descending order of importance.
 | **Criteria*** *thorough identification of relevant trends, patterns or relationships*

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.
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| **Analysis of data uncertainty and limitations** * There is only one criterion for this section, but spend some extra time here as 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 separagraphtely.
* 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. Do each of these in the one paragraphgraph.Start by calculating an average percent uncert from the uncertainty values in your secondary data table. A high average percentage uncertainty (>10%) indicates that the data has significant uncertainty. A low average percent uncert (<5%) means you have low uncert in your data. Of course, the individual percent uncert’s in the secondary data table may vary, so sometimes you need to discuss these individually rather than using an average. Then identify anomalies. Have you identified many anomalies within the trial data? 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 need to say this, or say there there were no anomalies, and the percent uncert is a true measure of uncert in the data.Lastly identify the uncertainty in the trend. You are likely to 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 and relationship. See sidenote about R2.The cause of the uncertainty should be listed and briefly described in terms of random or systemic error within the methodology. Limitations – 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 four ways to find limitations are:1. The simplest is if you have high uncertainty in your data. Using only 3 (or however many you used) trials has limited the precision of your data. Need more detail and evidence than this, but that’s the idea.
2. Also simple is if you have high uncertainty in your trend. Using the number of variations of the independent variable that you did (should have at least 5), has limited the precision of the trend. Need more detail and evidence than this, but that’s the idea.
3. Is there enough variation within your independent variable? Your range of variation may to very 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 relevant to situations outside your experiment. This is unlikely, but possible.
4. Are the values of your independent variable an exact match for real life situations? 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 situations which realistically represent 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 used in real life. This limits your ability to use the conclusions to answer the RQ.
5. 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.
 | **Criteria*** *thorough and appropriate identification of the uncertainty and limitations of evidence*

**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.

**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 trend or data. It 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 * Uncertainty in your data or trend
* 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.

EXPERT TIP: Your work in uncertainty and (especially) limitations are probably things that you will restructure several times. You will rely heavily on both of these when it comes to evaluating the reliability (using uncertainty) and validity (using limitations). The arguments in this section and the evaluating section are likely to be the most cognitively complex in your assignment. Spend some time away from your desk carefully thinking through your arguments here.  |

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| **Interpretation and Evaluation** (5 marks) – three criteria; you will write directly to each criteria. |
| **Conclusion*** Conclusions are usually not long. There should only be one or two paragraphs in your conclusion. Generally speaking, one paragraph for each conclusion, unless it is complex.
* Each paragraph should have a topic sentence that is the actual conclusion and is an answer to the RQ.

Firstly - The paragraphgraph should start with a conclusion relating your independent variable, your dependent variable, and your RQ. This is your main conclusion (be careful you do not simply restate your trend). If your conclusion 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 RQSecondly – Support this conclusion by using the trend(s) you identified. This is likely to be a detailed description of the mathematical relationship you have determined if you have one, and restate the math relationship you found as this is really the end product of your conclusion. 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* and the *justifying* part of the criteria. If you can make another conclusion, start another paragraphgraph and do the same thing.  | **Criteria*** justified conclusion/s *linked* to the research question

**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 trends (don’t repeat the use of data you used in the identifying trends section). **Cognitive verb explained** - *linked*Your teacher will most likely look for both of the things below: * the language used in your conclusion reflects that of the RQ, and your conclusion is an answer to your RQ. Ideally you did this in your first sentence.
* describes meaningful implications of (or predictions from) the conclusions, which directly relate to the research question (this helps with “*linked*”) and real life situations (this helps prove “*justified*”).
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| **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 separagraphtely; and most teachers find it easier to give you’re a good grade if you do them separagraphtely (and well).* 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 based in the data, trends, and conclusions; you need to include references (at last one) to the experimental process (I find the word – methodology useful for this – check out the exemplar).
* **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 have significant uncertainty lack reliability. This indicates your methodology was not reliable, and also that the conclusions you made are not reliable (remember to say this about the experimental process AND conclusion)
* **Validity** generally refers mainly to the trends you identified and conclusions you made relate accurately to the real world. 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):
* The most likely reason is - your uncertainty is too high (this mainly impacts reliability, but also validity as it means your conclusion could actually vary from what you did conclude), you did not measure what you intended to measure because there was not enough variation in the indep variable; your variation in the independent variable does not reflect real life conditions; you did not control the controlled variables well enough.
* whether your experiment method accurately reflects your research question (hopefully this NOT likely to be true).
* 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. If your can do this and you have significant error, your conclusion is not valid.
 | * 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.Check out the exemplar for examples of how these arguments are used. |
| **Improvements and Extensions**You must suggest both improvements and extensions, and include several improvements and at least two extensions. I recommend discuss improvements and extensions 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 by linking the improvement to the limitations and the data. This means each improvement you suggest should relate to a limitation you identified, and must be explained by discussing how this improvement will provide better 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? Usually this means changing the independent variable, dependent variable, or the context – acceptable and easy options. You may recommend an extension because your data did not cover the entirety of your research question. It is harder to provide evidence that an extension is “*logically derived*” from the analysis of data. However, you must try to provide that evidence! | * *suggested improvements and extensions to the experiment that are logically derived from the analysis of evidence*

**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. |

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 |