0.1 Writing the IA

0.1.1 Thoughts on the Order of Things

The IA is an extensive assignment testing and developing many of the student's skills. Due to this complexity, science IAs can sometimes have very elaborate marking schemes/tip lists. These are very useful for not loosing marks and should be consulted during the writing process. They however are not always explicit/helpful when it comes to developing a clear argument and making logical explanations.

The coherence and brevity of your work is one of its most valuable characteristics. No matter how amazing your hypothesis, experimental setup or data analysis is, if it is presented in a way that cannot be comprehended, it is unlikely you will score highly.

It is useful to have the following general structure of your IA.

1. Scope
2. Background Knowledge
3. Hypothesis
4. Experiment (procedure, materials etc.)
5. Data Analysis
6. Conclusion

These are very general sections, and SHOULD be modified/enlarged based on what suits your question best and has the best logical flow. This entirely depends on your topic and hypothesis.

The only way you can write and structure clear explanations of your scientific topic, is by having a very strong understanding of what you are trying to show/say within your work. This doesn't just require a lot of research, but most importantly a lot of time. In order to be as efficient and un-time-stressed as possible, I work on my IA in an order that let's me understand my investigation before I start writing about it.

1. Hypothesis & flesh out Background Information sections
    - Your hypothesis should be completed before you finalize and submit your topic. It does not have to be explicitly written, but when you start working on your IA with teacher's approval, you should know exactly what you are looking for.
    - Ideally, you will have some kind of formula that you have derived on your own, ready and written down. Sometimes this is also not possible due to time constraints. In this case you should at least now how you are going to achieve this formula and have an idea that it is even possible. (In Physics, this mostly comes down to writing down a system of equations and seeing if they are solvable.) Soon after, you should start thinking of your linearization.

- If you can only make a qualitative type hypothesis, make sure you have a strong backing that relies on your initial assumptions (or someone else's work). You also should have an idea of how you will measure your independent variable with as much detail as possible.
- Same rules apply to the "type of hypothesis". By the time of submitting the topic, you should already have your choice of relationship and reasoning behind this choice.

2. Experimental Procedure (may be swapped places with 3)
   - This step does not necessarily have to be done in this order. Some experiments can be very easy (especially in physics where half the time you are just dropping a ball), and will not require an overly elaborate procedure. You should still have a good idea of what you will be doing in the lab, but sometimes a good idea is just enough to figure it out on the day of (this is very very very untrue for chemistry (but this also depends)). Sometimes, the order of this step is influenced by how close my experiment day is.
   - Either way, you should at least have an idea of what kind of data you will be collecting / what you will be measuring, as this is imperative for your next step.
3. Writing Data Analysis Code
   - Under no circumstances should you be analyzing your data by hand. Computers have been invented for a reason. They can do many calculations over and over again really fast. More importantly, when you make a mistake (and you will make many mistakes in your data analysis the first time around), correcting it will be much faster and simpler (in most cases, just rewriting a single line of code), rather than having to manually redo pages worth of calculations
   - You should begin writing this code before you conduct your experiment. This will help you finally bridge your understanding of the hypothesis and experiment into one single coherent thought. (Note, that up to this point, we have not yet written much of the IA, but rather did supplementary steps that will help us in the long term)
   - Ideally you will finish this before (or soon after) you have conducted your experiment
4. Do your experiment
5. Begin writing your Data Analysis Section
   - This step is also interchangeable with the next step. Now that you have written your code, you know how you will analyze your data, and can start writing out this explanation
6. Run your data through your code, make tables & graphs

- Never leave this to the last moment! There will always be errors in your code that will take some time to fix (at least the first couple of times).
- Formatting graphs and tables can also take a while. Do this step ASAP

7. Finish Data Analysis Section

   - Once you have processed all of your data, you can start writing your sample calculations and putting your graphs into your document

8. Literally everything else

   - At this point you have finished everything. You wrote your hypothesis, you verified it and should be more than familiar with your question. It doesn't matter what order you write the rest of your work in.

0.1.2 Thoughts on Clarity

The order in which you present your ideas can greatly influence readability and flow of your writing. While this may sound obvious, this aspect is often neglected and leads to poor quality work.

1. Visually separate your ideas

   - Adding spaces between paragraphs can make a huge difference in how easy it is to follow your writing.
   - Split things into sections with headers and subheaders and subsubheaders. This is the best visual way to separate your thoughts (long walls of text are difficult to read.)

2. Contain your explanations within its own part /section.

   - Never go on a tangent in the middle of an explanation. Even if this "new" idea is meant to help prove your point, it is very distracting for the reader to have to shift their attention to a new thing and then try and return to some previous unfinished point. You can always introduce this supplementary idea separately, before you begin the explanation.

3. Use Diagrams

   - Many things can be expressed visually much better than in writing. Draw diagrams.

4. Reference things

   - Remember that the person grading your IA is possibly learning the topic for the very first time, FROM your IA. If you are referencing previously mentioned ideas, it may be useful to say where they came from. E.G. the law mentioned in section 0.2.1 .

- All important formulas and equations should be assigned a number, and referenced later using that number (same goes for Figures and Tables).

Last and final thing is tone. Avoid using "non-physical" adjectives. This writing has to be very specific and to the point. Make sure you use descriptions that mean exactly what is happening. This is not an English essay where you can call things "exuberant", "foreshadowing" etc. Once again, if you feel that taking something out will not change or worsen understanding, it is probably more confusing than helpful!

0.1.3 Sample

Let's look at and deconstruct the sample IA found in the IA section ***here*** in the same order as they were written.

*Note that this is where quite a few things can be really subjective.

0.1.3.1 Hypothesis & Background Info

I begin by stating all of my initial assumptions I will be later using in the Background Info section. Note that I do not include any information that I did not reference later in my IA.

E.G. If your work is vaguely connected/applicable to global warming, do not write 3 paragraphs about it! That is simply not the point of your investigation and is therefore entirely irrelevant! My personal rule of thumb is: if I don't use this information later, it is probably useless. This is why I write the Background Info section along side the Hypothesis. This way I will definitely not forget to include the necessary things.

In the Hypothesis section, I begin by introducing my physical system. Then, based on my initial assumptions I "logic out" a hypothesis that is "semi-quantitative" and describes the "type of relationship" I can expect. Note that I attach a diagram to aid in my explanation.

Note how all equations are written on their own line, (not as part of a paragraph). This makes your writing much clearer. While it is acceptable to have math inside of paragraphs, if you use that equation later outside of the paragraph, it is best to center it and assign it a number.

For every important equation, I have a separate list which explains the meaning behind the variables. This allows the reader to directly understand the formula without having to re-read all of the paragraphs above.

Try not to use the same variable for two different things, this can really get confusing and change meaning. Same goes to "similar variables". (The opposite can however be true, when you are using a lot of variables, and choose similar variables when describing similar things).

In the very end I make my actual hypothesis statement, where I say exactly what I predict will happen.

0.1.3.2 Experiment

Begin by stating the required **Materials and Equipment**. These should be separate sections (simply more clear that way)!

Note that all measurement equipment is listed with its associated uncertainty (how accurate the equipment is).

Materials are listed with specific quantities.

In this case the sample does not do a good job, because it does not specify exactly how much water is needed. It also does not specify the exact surface areas of all of the jars.

Note that there often exists equipment used to directly measure your variable, so that you do not need to come up with a lot of weird ways to collect data. Ask your teachers about equipment that may help you.

The **Procedure** is written in paragraph form, not as a list. This takes up less space and allows you to be more descriptive.

Some teachers/classes may accept list type procedures. In this case, try to avoid using excessive recursion (do not have a lot of steps that tell you to go back to/repeat previous steps. This can be confusing and hard to follow.

A **variables** section is often required (and generally quite useful). Its functionality can change from subject to subject. Sometimes it is needed to simply match mathematical symbols and their real life quantities. In this case, I also use it to justify/explain how different aspects of the procedure allow the hypothesis to better reflect the experiment. I therefore placed it after the procedure, (sometimes it can be placed before).

0.1.3.3 Data Analysis

I start of with a **Methodology** section. Here I explain how I intend to analyze my data. I state any formulas that are relevant to data analysis only and do not really fit in other sections (E.G. uncertainty calculation). I prefer to write all of this in a separate subsection, rather than together with the sample calculations, so that the flow of my explanation is not broken up by said calculations.

Once again, all relevant equations are assigned a number and the meaning of all variables is explained.

The **Raw Data** is presented in a table (somewhat poorly formatted in the exemplar) with a detailed title that has as much detail as possible. Your titles should never just be " water level vs time". Include all relevant information, so that you do not need to read anything else to be able to understand the table. The same goes out for labeling **graphs**.

Sample Calculations are not overly complicated. You simply have to reference your formula you are using, state where you are getting the data from, rewrite the formula, plug in the numbers and write your final answer. If you use special software functions (E.G. Lines of best fit), it is acceptable to just write what you are doing and write the final answer. Remember, you do not need to show every calculation; just one of each.

Sometimes you many need to use one calculation in another calculation (you have multiple steps). In this case, it can be useful to have separate charts/tables with partial step results.

Graphs have properly labeled axes, and have descriptive titles (see the Raw Data note).

0.1.3.4 Conclusion

This can also be written in many ways. Different teachers have different advice on structure and you should follow it.

There are however important do's and don't s

- DO reference all of your Data Analysis you have done in the past to make a judgment of your hypothesis.
- Clearly state if experiment agrees/disagrees/partially agrees with your hypothesis.
- This is a bit strange to say, but try and avoid speaking of you work in a bad way.
  - Even if your hypothesis was wrong and you got nonsense data, select your words in a way that you do not have a negative tone. Under no circumstances should you lie, or make it sound like you are right, just don't say that everything you did is wrong (otherwise why would you have done it?)
- **DO NOT PANIC**
  - It can happen that your data is completely different from what you have predicted. THIS IS NORMAL. YOU WILL NOT FAIL YOUR IA (unless your hypothesis was not logically sound you are just dumb).
  - You still have to reach some conclusion using your data analysis. As long as you write that out properly, it doesn't matter if you were right or wrong. You used the scientific method and demonstrated that you could do it.

This Sample IA could be greatly improved if the calculated coefficients had some "expected" value from other sources, we could compare them to (I didn't really check). This can be used to validate the result etc.

0.1.3.5 Limitations and Extensions

This is once again a section that can be written in many ways. I personally like the structure provided by the chemistry department.

This section will consist of paragraphs for each thing "wrong" with your data. They will have the following outline:

1. What you saw in the Data Analysis that didn't make sense
2. What you think could have caused that
3. How can you fix it (how to change procedure)

There are two issues that are applicable to almost all IAs.

- Equipment was not accurate enough - Get better equipment
- You assumed something was constant but it actually wasn't - find another way to keep that variable constant (E.G. Temperature/humidity etc.)

NEVER EVER list "human-error" as a limitation of the experiment. "I messed up" is not a useful reflection. Here we are looking for systematic error.

Sometimes you can also propose improvements of the mathematical model in a separate paragraph here as well.

Limitations and Extensions should be a separate section. This should not be in other parts of your IA (otherwise reading can be confusing E.G. Why are you doing this, if you just said it is no good?).

0.1.3.6 Scope

This is the intro portion of your work. I normally write this last, as it is least important to actually answering my question/proving/disproving my hypothesis.

Here you should mention why your "theory"/mathematical model will be useful. This normally comes down to you saying "this process I am investigating is used in these industries. A way to predict how it works can help: bring costs down, make planning more efficient (or whatever is applicable). To test the theory, we will use a simplified system from what is used in industry".

Of course, other uses outside of industry should also be mentioned (this doesn't have to be the main focus. It is just the example I used.

0.1.3.7 Missing things

The Sample IA does not include a safety and ethical concerns section. When working with certain materials (such as Acid, potentially sharp equipment) you must include this section outlining possible health hazards in the procedure and what can be done to avoid them. A really easy way to fill this section out in a professional manner is to read Material Safety Data Sheets (MSDS) online.

0.1.3.8 The Personal Engagement Issue

In the IA rubric, there is a criteria for personal engagement. This often causes people to write separate paragraphs on the importance of this topic/investigation to them personally. This immediately raises the question of "So can I use personal pronouns?".

The answer to this question completely differs from teacher to teacher. My own suggestion, would be to have this is an entirely separate section where you write some personal reflection, this being the only place in the IA where you use "I".

Personal Engagement however can be demonstrated through other means. Specifically, if it looks like you put in a lot of work into your IA (you derived a really cool unique formula, found and interesting way to analyzer your data, your experiment was complex) that shows that you were engaged with your work!

The Sample IA would have still probably benefited from this section as it is not all that complex.