Biology, Chemistry & Physics: Guidelines for Individual Investigation marking

**Thumbs up symbol:** These could be clarifying examples of aspects to look for in order to give credit for a criterion, or in cases where you will be actively marking positively and showing support of the candidate and the teacher in borderline judgements.

**Thumbs down symbol:** Limitations that will reduce the descriptor level, or will require referral to your team leader are annotated with a thumbs down.

**General Advice**

*Read the whole report first* to gain a general impression before attempting to establish marks. Evidence for particular criteria may appear in several parts of the investigation.

*Use a best-fit approach.* The aim is to find the aspect within a criterion that most accurately conveys the level attained by the candidate. This approach means that compensation can be made when a piece of work matches different descriptors of a criterion at different levels.

*The overall mark per criterion is not an arithmetic mean,* and only whole numbers should be awarded. Fractions or decimals cannot be entered.

*Teachers have been advised to read the aspects for each criterion starting with the lowest,* but examiners may moderate using the teacher's marks as a starting point (i.e. looking for evidence, going up or down or accepting marks awarded as necessary).

*Examiners may mark by initially giving careful consideration to the teacher's mark and comments* and then looking to see if there is clear evidence to adjust the mark upwards or downwards. If you feel that the teacher has made a sensible interpretation of the criterion in question the mark should be supported.

*Mark positively.* Look for what is present in an investigation rather than minor omissions. Instead of questioning whether they have included everything, ask "have they said enough to meet the descriptor level?"

*Where there are two marks available within a descriptor level* the upper marks should be awarded if the investigation demonstrates the qualities described to a greater extent (the work may be closer to achieving marks in the level above). The lower descriptor level would apply if the candidate's work demonstrates the qualities described to a lesser extent (the work may be closer to achieving marks in the level below).

*"Does your final moderated mark look fair?".* On samples where you support the overall mark, small disagreements with the teachers mark within a criterion may be seen. **Allow these random uncertainties to cancel out.** However, if the marking of a criterion is consistently harsh or lenient, consider moderating the mark up or down respectively.

*Be open-minded and try to reward independent thinkers and risk takers.* A candidate may have produced work that fulfils a criterion in a way these guidelines have not foreseen. Let the work in front of you define the outcome.

*If there is no achievement against one of the four descriptors* within a criterion (with the occasional exceptions of the safety, ethical, environmental aspects of the Exploration criterion, when there is clearly no relevant issue to address), the overall mark for the criterion will most likely be impacted but this should not be over penalized.

**Double marking considerations might happen,** especially regarding investigations which generated limited data; there may possibly be an impact on Exploration, Analysis and Evaluation.

*If the investigation is so far removed from the intended subject,* and you feel unqualified to mark it, please contact your team leader for further advice. The IB may also need to cross check that the candidate has not submitted the same work for two sciences, or for their extended essay also.
Personal Engagement (PE)

PE should be assessed across the whole report even if the candidate has presented a section entitled "Personal Engagement".

Independent thinking, initiative or insight could be evidenced by:
- the setting of the scientific context for the research question (RQ) – Does it evidence genuine curiosity?
- the choice of sources for the background;
- the design of the method;
- the choice of materials;
- the choice of methods for the analysis of the data;
- the interpretation of the data;
- the conclusions drawn;
- the evaluation of the method and data;
- the setting of the scientific context for the conclusion.

Possible reasons why the work may not meet the highest band:
- The candidate is not showing curiosity such as presenting very undemanding RQ where the outcome is well defined in syllabus or self-evident.
- The report describes a "commonplace" school investigation with a procedure that has not been adapted or extended in any way.
- The data presented does not appear to be sufficient to justify an action phase that should have occupied a majority of the time allocation.
- There were clear limitations in the initial methodology that could have been quickly and easily addressed during the process but the candidate made no attempt to do so.
EXPLORATION (Ex)

Research Question

The RQ may not be phrased as a question. As long as the purpose of the investigation is focused and clear then this can be fully credited.

If the independent variable is not measured quantitatively there is still opportunity to achieve well. There is interesting and valid research where the independent variable is not measurable and these can fulfil the first aspect of the criterion completely.

The 3-4 mark band states: "The topic of the investigation is identified and a relevant but not fully focused research question is described." This is also the correct band for "a focused but not fully relevant research question", i.e. those cases where an interesting topic has been identified but then the candidate's RQ is only weakly linked.

The straightforward comparison of two organisms or "brands" probably represents a weak RQ since the underlying cause of any difference does not arise from any scientific principle.

Background

Background relates to the theoretical context given.

General accounts of the broad area of study rather than evidencing background reading around the exact research question will not meet the 5-6 mark band: "The background information provided for the investigation is entirely appropriate and relevant".

Method

Candidates do not have to explicitly list the variables however, from the methodology it must be clear that the dependent, independent and control variables have been appropriately considered. The methodology "...takes into consideration all, or nearly all, of the significant factors that may influence the relevance, reliability and sufficiency of the collected data". Of course there is no problem if the variables are listed and explicitly identified.

Standard protocols for determining the dependent variable, which have been taken from another source, may be used. Although acceptable, these must be referenced. Within a wider context, candidates can use a standard measurement method.

There is no longer a prescribed minimum number of values of independent variables since different types of investigation will facilitate very different amounts of data. Key considerations on whether an investigation meets the third aspect (relating to sufficient, reliable and relevant data) should be:

- How demanding and time consuming is the collection of data? Has this legitimately limited the number of values of the independent variable collected?
- Do resources normally available in a school make it unrealistic to expect four or more values of the independent variable?
- Repeats (or comparison of sources) are nearly always going to be necessary to establish reliability.
- In some cases where the data is readily collected it could be reasonable to expect more values of the independent variable to be collected within key ranges to correctly establish a trend.

A materials list is not obligatory and should not be penalized if missing. Details of the materials can be given in the method.

The method needs to make provision for sufficient data to be collected to answer the research question in an action phase that will occupy a majority of the time allocation. It isn't unreasonable to expect a significant number of independent variable values and/or repeats as well as consideration of calibration of some apparatus.

Overly simple or imprecise methodology and procedure satisfies aspects of the 1-2 mark band. The methodology "...takes into consideration few of the significant factors that may influence the relevance, reliability and sufficiency of the collected data".

A poorly written up methodology that has not included enough procedural detail to reproduce the research should be assessed in the Communication criterion, not...
Exploration. If however, after looking at the whole investigation, you realise that they have not sufficiently controlled variables or generated sufficient data, this should then be reflected in your mark for Exploration (third aspect).

Safety, Ethics & Environmental Impact

Where there is clearly no issue with safety, ethics or environmental impact, there may be no need for a statement. If there are no relevant safety, ethics or environmental impact factors then this aspect is excluded from assessment.

Where there would have been relevant safety, ethical and environmental issues, but these would not have been immediately obvious to an IB candidate without a teacher’s or examiner’s prior knowledge and experience, give the candidate the benefit of the doubt, if they have not included an evaluative statement.

Typical considerations of safety, ethical and environmental issues that are reasonable to expect consideration for:

- The safe handling of equipment and chemicals;
- The correct disposal of wastes;
- A sustainable consumption of materials.
ANALYSIS (A)

Raw Data

Certain aspects ask for "quantitative and qualitative data". The requirement for qualitative data is only where it is relevant to allow the research question to be answered. In some investigations, such as those using data logging, we do not want to see many pages of raw data since we are now valuing conciseness and clarity. A sample of data (ideally, with a note to that effect) and summary table of average data may be considered acceptable.

Processing

In particular, this looks at the correct and complete processing of raw data. Good achievement will be possible in reports where the candidate has averaged the dependent variable data and then plotted a graph to see the nature of the relationship. Very often this is the most meaningful analysis. If the RQ and methodology lead to very limited data but this small amount of data is recorded and processed correctly do NOT be tempted to over-reward. The new IA places the responsibility on the candidate and part of the independent learning task is for candidates to be aware of the criteria.

Uncertainties

Some factors that may contribute towards evidencing consideration of uncertainties:
• Error bars on graphs;
• Well-constructed lines of best-fit (do not blindly accept poor Excel polynomials!);
• Maximum or minimum slopes;
• Appropriate consideration of outlier data;
• Consideration of equation of a line and the $R^2$ value;
• Consistent significant figures and decimal places;
• Sensible protocol on propagation of errors through numerical calculations. This could be as outlined in books, the old subject guide or the teacher support material (TSM) provided to schools, standard deviations, square rooting some of the squares, statistical analysis, etc.;
• Comparison of data from different data sources (secondary data examples) to evaluate variance;
• Evidence of investigation of research into the uncertainties associated with database data.

We do not expect all of the above. This is just a guide to the ways in which a candidate may evidence consideration of the impact of measurement uncertainty on the analysis. Be open minded and support the teacher if the attempt by the candidate has been sensible and consistent even if it is not the protocol you expect in your class. Also a minor slip in the analysis of uncertainties should not lead to a candidate automatically losing credit for a large amount of correct data processing.

Interpretation

This is the process of making sense of the data that will then lead into a conclusion. Look for evidence such as the explanation of trends, comparisons, correlations, optima, maxima (plateau) or the correct interpretation of the results of statistical calculations. If the data collected and processed does not finally lead to clear patterns or trends then the efforts of the candidate to make sense of the data objectively should be rewarded. This part of the Analysis criterion does cross into the first part of Evaluation and there is an element of double credit or double penalty.

When interpreting a graphical relationship do not over-reward the thoughtless presenting of the Excel best-fit equation as the outcome finding. There is more value in a candidate recognising the relationship to be linearly proportional, inversely proportional, exponentially proportional, etc.
EVALUATION (Ev)

Conclusion

A statement or discussion of whether the data answers the RQ should be presented. Thus, it should refer back to the RQ and be scientifically justified with comparisons made to properly referenced background material.

If a hypothesis has been proposed then the candidate should conclude whether the data does or does not support it.

It is most likely that the data may go some way to supporting a conclusion but will rarely be sufficient to be considered incontrovertible evidence in a school-based investigation.

Scientific Context

The context needs to be relevant. It may refer to the correct scientific context presented in the background information, or accepted literature values. If there is no accepted value available, the findings need to connect to the relevant scientific context to provide justification the candidate used the scientific context to show or prove that the findings are reliable.

Weaknesses & Strengths

Obvious weaknesses that are consistent with the direction of error should be identified and addressed. Consideration of both the strengths and difficulties and the quality of the data and processing is needed. These should not include errors due to sloppy manipulative skills or hypothetical events for which there is no evidence.

If a candidate reflects on how their conclusions could be more valid and justified by adapting the method to address underlying factors such as range, sample size, the use of an alternative reaction system to study the same phenomenon, etc., this is considered an evaluation of the methodology. It is recognised that procedural issues are not trivial, however high achievement in evaluation will arise in reports where the candidate has a strong understanding of the methodological issues involved in establishing the conclusion.

The evaluation of the nature of the experimental errors (random or systematic) or weaknesses should be consistent with the findings and not overstated. As part of this process the candidate shows an understanding of a source of error relative impact on the reliability of the findings. However, the candidate’s comments on significance of sources of error must be consistent with direction of error.

A candidate who only addresses practical or procedural issues, by simply giving an account of how their results could be improved by carrying out their stated procedure better, only fulfills the lower band of this descriptor.

Suggested Improvements & Extensions

Both suggested improvements and extensions should be precise, focused and relevant to the investigation. The potential implication of these modifications and how they might bring the experimental results closer to what is expected are discussed.

The improvements must be related to the weaknesses identified and they should be feasible in the context of a school environment or field course.

The extension suggested should follow on from the research in a meaningful way and show how it will enhance understanding of the topic or RQ. It is clear why knowing this may be important.
COMMUNICATION (C)

Structure & Clarity

The style of presentation of the methodology is flexible with no prescription in issues of passive versus personal voice or prose versus a stepwise procedure.

Do not automatically mark work down on the page limit restriction for including an appendix.

As stated earlier: a poorly written methodology that has not included enough procedural detail to reproduce the research is a matter for Communication not Exploration. If however after looking at the whole report you realise that they have not sufficiently controlled variables or generated sufficient data then this is reflected in the Exploration criterion.

The contents of the appendix should not be given credit. You are not under any obligation to read the appendix and no information of direct relevance to the analysis and argument of the investigation should have been included.

Referencing

If a candidate clearly stated they are using someone else’s ideas or data (e.g. a literature value which is labelled as such), but have made errors in how they have written up the source then that will not require reporting as an academic honesty issue.

Structure is also evidenced by the use of headings and subheadings, and using diagrams and images to enhance interpretation.

An investigation that is clear will be coherent. It will be easy to understand the thinking process used by the candidate throughout. This can include showing clearly presented raw and processed data and sample calculations (e.g. steps involved in data processing).

When the candidate has used information from another source but there is no clear acknowledgement of where or how it was used, this may be considered academic misconduct and must be reported to the IB (by raising an exception). If it is felt that material has been plagiarised it should also be reported to the IB (by raising an exception). We should however distinguish between sloppy communication and deliberate academic misconduct.

Relevance & Conciseness

The work remains closely connected and appropriate to the topic and question under investigation. It retains this focus throughout, making it easy to follow the development of the ideas from beginning to end.

The research is concise and does not include extra or unnecessary or repetitive information.

The candidate should submit to the teacher an investigation of 6-12 pages in length without automatic penalties for a report that is slightly longer, as long as the report remains relevant and concise. The page count includes the appendices but excludes the IB generated 4/ICCS cover sheet (which the school uploads separately). Conciseness should be judged on the work submitted by the candidate. So, if a teacher marks up an investigation which leads to the page count exceeding the limit, the candidate should not be impacted. The statement: “The report is relevant and concise thereby facilitating a ready understanding of the focus, process and outcomes of the investigation” is more likely to be achieved by a report of this length. A sensible stance in relation to presentation with regard to font size and margin width should be held, to ensure that good communication skills are demonstrated. In the same way, graphs should not be reduced to such a size that they become uninformative, simply to stay within the page limit.

While the IB have given schools general formatting suggestions, these are not compulsory to follow.

Full calculations are not expected to be shown, examples will suffice, and a worked example from a calculation carried out on a spreadsheet or a programmable calculator will not be expected.

Subject-Specific Terminology & Conventions

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High achievement will be evidenced by correct formulae, nomenclature, mechanisms, significant figures, decimal places, units and other scientific terms and definitions. Consistent precision in recording and presenting raw and processed data and associated ± uncertainties. To achieve in the higher aspect of a criterion, the terms and conventions do not have to be perfect and completely free from error. Candidates are expected to use SI units throughout; use of accepted derived units like L and mL are acceptable, but imperial units (oz, inches, F) and other units (e.g. cooking conventions) are not. Incorrect use of terminology may include incorrect or missing units, repeated errors, missing uncertainties on raw data, inconsistent use of significant figures, incorrect use of terms. Inadequate labelling of graphs (axes, legends, titles) and data tables (e.g. headers) may impact on Analysis as well as Communication if it makes the data incomprehensible.