**Individual Project**

**For Biology / Chemistry /Physics**

**Research Question:**

***Formulate the research question and make sure that***

***both dependent and independent variable are quantifiable.***

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| **Personal**  **Engagement (2)** | **Exploration**  **(6)** | **Analysis**  **(6)** | **Evaluation**  **(6)** | **Communication**  **(4)** | **Total**  **(24)** |
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1. **Exploration**

**Exploration – Topic and Research Question**

* A precise and focused research question
* Dependent and independent variables are identified and measurable
* You can also include a hypothesis (which is justified) to explain what you expect as an outcome and why.
* Common problem: Students often formulate the research question to general. The variables are often not measurable.
* Common problem: Often students think that they change one variable, but they change several. Eg. “Investigating plant grow dependent on the type of soil used.” Type of soil contains several variables. Better to have different soil/sand mixtures.

**Exploration – Significance of the Topic**

* Personal significance or at least significance of the research question is explained. Why is the RQ worthy of study? Why is it worth your time?
* Common problem: Students are happy that they have found any RQ at all, and they can not think of a good reason why it should be investigated.

**Exploration – Background information**

* The background information must be directly relevant to the research question. This information helps the reader to understand the RQ. This includes theory.
* Common problem: Too much irrelevant material is mentioned; References missing.

**Exploration – Safety and ethical issues**

* Mention safety and ethical issues. Ethical issues can include animal rights, environmental protection issues as well as health issues. Dangerous chemicals involved? Animals harmed? Water contaminated?
* Common problem: Sometimes there are no obvious ethical issues. Students then should say this and justify why there are not ethical/safety issues. But it is better to be creative and suggest realistic ones.
* Common problem: Sometimes students invent ethical concerns, even though they are not relevant. (“We do not know if plants feel pain and therefore we have to treat plants with respect.”)

**Exploration – Overview method**

* Give an overview method of your experiment. Many students start right away with a detailed method, but this is too difficult to understand.
* Example: “I intend to measure the bacterial density of my dog’s teeth dependent on the amount of toothpaste used.” This is understandable. But if you start right away with “1. Take a dog and put toothpaste on the toothbrush”, then nobody understands what your experiment is going to be about.
* Common problem: Students give too much detailed information and quantities in the overview. Detailed measurements are not needed in the overview (this is done later).

**Exploration – Materials used**

* Be specific here and indicate the size of beakers etc.
* What do you need the scissors for? The tape? You have to explain what you need it for!
* Common problems: Sometimes irrelevant material is listed (you do not need to write: “Computer to evaluate the data” or “Pen to write down the results”)

**Exploration – Control of Controlled variables. You can use regular text, not bullet points.**

* Controlled variables are those factors that have to be kept constant.
* How do you keep them the same?
* Why is it relevant to keep them the same?
* Common problem: Students sometimes list irrelevant factors, and they do not know a justification. Example: “The gravity has to be kept the same because maybe it influences plant growth.”
* Common problem (a VERY common problem!): Students do not say HOW the factor is kept the same. They say “We have to keep the air temperature the same for all test runs, and this is important because all the beakers should be treated the same way.” Better: “We have to keep the air temperature the same and this is done by doing the experiment in the same room and making sure that doors and windows are closed.”

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| Variable kept the same | How it is kept the same | Why it is relevant |
| Bad: Temperature | Bad: We keep it the same | Bad: So that the yeast respires the same way |
| Better: Temperature | Better: By heating the water to 45°C in a water bath | Better: Yeast respiration rate is highly temperature dependent. A temperature higher than 45°C might kill the yeast and a temperature much lower will result in too little CO2 production. |
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**Exploration – Control of the Independent variable.**

* This is the one variable that you change. How do you change it? Range? What determines the range?
* Common problem: Students do not know what range to use. Eg. How high do rubber balls bounce when heated to different temperatures? What temperatures should be used? Are the steps between the individual temperatures too small / large? Pre-experiment necessary.

**Exploration – Measurement of Dependent Variable.**

* How do you measure the outcome of the experiment?
* How often do you measure it? Why not more often or less often?
* Common problem: Sometimes students only do the experiment once.
* Common problem: Sometimes students repeat the experiment too often but do not justify why it is necessary. They just write something like: “The measurement will be repeated 100 times”, but actually 10x would have resulted in sufficiently good results. They just say 100x without thinking about it.

**Exploration – Method for Data Processing.**

* What calculations are you going to do on the collected data?
* You describe the strategy of processing the data, you do not actually process it at this point.

1. **Analysis**

**Analysis – Raw data**

* Include the raw data table here
* You can also include the processing here, eg averages, if it makes sense
* Describe the trends of the raw data.
* Indicate measurement uncertainty!
* Common problems: units written next to values and not in heading; missing title and caption; title and caption are the same (no extra information); wrong number of significant digits; and many more points.
* Common problems: Only a data table is presented, without explanatory text; explanatory text does not reference the data table.

**Analysis – Processing**

* Sometimes it makes more sense to combine the data processing with the raw data (eg. when calculating % or averages). You do not need to have a separate section.
* Perform calculations on the raw data.
* Do not forget about standard deviations, averages (if relevant)
* Include % calculations, include differences….
* Common problem: Sometimes irrelevant processing is performed. Eg. water cools down from 100°C to 50°C and a measurement is taken every minute. The student then averages these temperatures. You only average repeats.

**Analysis – Measurement uncertainty**

* How big is the measurement uncertainty?
* What impact does the measurement uncertainty have on the result?
* Common problem:

**Analysis – Graphs**

* Must have lines of best fit, standard deviations etc.
* Processed data must be graphed, not raw data
* Common Problem: Directly graphing the raw data is not data processing, it is presentation of raw data. Need to draw a graph of processed data.
* Common Problem: No line of best fit drawn. Line of best fit is a form of data processing.
* Common Problem: Averages graphed without standard deviation (error bars)
* Suggestion: Extrapolation of line of best fit is also processing

**Analysis – Qualitative data**

* Mention them and make it clear how this relates to the Research Question.
* Does the qualitative data support in answering the research question?
* Qualitative data is data that is not measured numerically (color change, change in smell etc)

1. **Evaluation**

**Evaluation of the Data**

* Explain the overall trend
* How good / significant is the collected data?

**Evaluation – Conclusion**

* Detailed conclusion, which makes explicit reference to the data and graphs.
* Common Problem: Students write conclusions that are not really conclusions because they do not refer to the data: “Overall the experiment worked out well and supported the hypothesis” is not a conclusion.
* The conclusion must make reference to an accepted scientific context. Is your data in agreement with published science? Research necessary here.

**Evaluation – Strengths of the experiment**

* The things that you would keep, when doing the experiment again.
* Why was it a strength?
* Common Problem: Sometimes students invent problems even if the experiment was fine.
* Common Problem: The strength was not justified.
* Common problem: Students are often not creative enough. They say: “Everything worked well”.
* Common Problem: Strengths are mentioned but not evaluated. Evaluated = to what extent.

**Evaluation – Weaknesses of the experiment**

* And also the extent of the weakness
* Is the weakness so problematic that it results in bad results?
* Common Problem: Weaknesses are mentioned but not evaluated. Evaluated = to what extent.
* Common Problem: Sometimes weaknesses are invented, which are not fundamental weaknesses. “We did not have enough time.” This is an organizational problem, and not a problem of the method.
* Common Problem: Students do not question the overall procedure of the experiment but focus only on the technical or practical problems
* Common Problem: Weaknesses are not justified and are convenience problems. Eg. “A weakness was that we used analog thermometers and not digital thermometers. Digital thermometer give a more precise result.” Why was this a problem? Why do you need a higher precision?

**Evaluation – Improvements**

* Significant improvements are necessary here. Not just trivial improvements like “I will do more measurements to get better results”. How many more measurements? What’s the point of more measurements, if they are flawed in the first place?
* Discussion of improvements means that you also talk about the degree that they are relevant.
* Improvements should reduce the standard deviation, errors, etc.
* Possibility: Combine Weaknesses and Improvements in a table.

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| **Weakness and extent of weakness** | **Improvement** | **How the improvement would improve the result, why improvement is relevant** |
| The experiment was not repeated [This is already a planning problem] | Bad: We should repeat the experiment more often [how often?] | Bad: The results would be better [why? How would it be “better”] |
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