LabWrite improving lab reports

Designing Experiments SelfGuide

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PostLab: writing your lab report

SECTION ONE : Methods

Describing the lab procedure

Using the notes you took while performing your experiment(s) and any other appropriate sources, describe in paragraph form the experimental procedures you followed. Be sure to include enough detail about the materials and methods you used so that someone else could repeat your experiment as you performed it.

More Help:

- In writing the Methods, you need to rely primarily on the notes you took as you were doing the experiment. Think of your audience as someone who does not know what experiment you performed. Include enough details about both the materials you used and what you did so that the audience has a clear picture of the experiment.
- Write the procedure in paragraph form. For relatively simple labs, one paragraph will do; more complex labs will take multiple paragraphs. Keep the paragraphs relatively short because it's hard for readers to process detailed information like this without sufficient breaks.
- Avoid putting any results of the lab in the Methods. Just describe what you did, not what you found.
- Use the proper past tense and passive voice. Methods are usually written in past tense because you are describing what you have already done. They are also typically written in passive voice ("Two ml. *were pipetted* into a test tube"). However, your lab instructor may permit you to use active voice, which uses first person, "I" or"we" ("We *pipetted* 2 ml. of the solution into the test tube").

More Helpful Hints:

- To make your description of the experimental procedure clear, use appropriate transitional or "sign post" words that indicate a sequence and help the reader follow the sequence: step 1, step 2, step 3; first, then, finally; first, second, third; after, next, later, following; etc.
- Include the methods you used for both gathering data and analyzing the data.
- If your lab is complicated, perhaps consisting of more than one experimental procedure, then consider dividing your Methods into sections with subheadings.
- If you used what is considered a standard procedure (one that competent scientists in the field are likely to be familiar with) then there is no need to describe it in detail. Simply state that you used that procedure, being sure to give its common name. (If you are not sure about what standard procedures are in

your field, ask your lab instructor.)
- When describing an apparatus or instrument, it may be better to include a sketch of it rather than to try to describe it fully in words. This is especially useful in cases where the apparatus is complex or designed by you. All you need is a couple of sentences that give a general sense of the apparatus, and then refer the reader to the figure that contains the sketch, the same way you would refer the reader to tables or graphs.

SECTION TWO : Results

Making sense of your data for yourself and others

Step 1: If you haven't already done so, put your lab data in visual form by creating appropriate tables, graphs, and other figures. Representing your data in a visual format will allow you to identify trends and relationships among variables more easily.

More Help:

- Establish what types of data you have, quantitative or qualitative (refer to the Resources page in the web version of this document; once there, choose "Data Types").
- Determine if the data should be represented as a table or a graph (refer to the Resources page in the web version of this document; once there, choose "Tables vs. Graphs").
- If you decide to use a graph to represent your data, determine which type of graph is one that best represents your data (refer to the Resources page in the web version of this document; once there, choose "Graph Types").
- If a table is the best format for your data, then modify the table you used to collect your data so that it is labeled and organized properly (refer to the Resources page in the web version of this document, once there, choose "Designing Tables").
- If you need help creating a spreadsheet to make a table or graph, refer to the Resources page in the web version of this document. Once there, choose "Excel Tutorial."

Step 2: Once you have generated visual representations of your data, decide the order in which your tables, graphs, or other figures should be presented in the Results section.

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If you have multiple data sets, you can arrange your visuals according to one of these methods of ordering:

- chronological order: if the lab consists of more than one procedure, you can present the results in the order in which you did the procedures, especially if that order provides a useful way of leading the reader through the results.
- order of importance: arrange the visuals by putting the one that is the most important first and then the others in descending order of importance.
- order of generality: sometimes it is better to start with the most general representation of the data and then place the more specific ones after that,especially if the specific ones serve to support the broad representation or add more details to it.

Step 3: Review all the data from your experiment. In a sentence or two summarize the overall results of this lab. This is the opening sentence(s) of the Results section.

More Help:

- In your summary, be sure to focus only on the findings, the data from the experiment. Don't address the hypothesis.
- Review the data in your visuals (tables and graphs and other figures). If you have trouble shaping a one- or two- sentence summary, look for a unifying feature among the data sets. This is likely to be the dependent variable. The sentence will be a general statement that summarizes your findings about that variable or related variables.
- You can start the sentence in several ways: "The results of the lab show that …"; "The data from the experiments demonstrate that…"; "The independent variable X increased as Y and Z were…."

Step 4: In separate paragraphs summarize the finding in each of your visuals--tables, graphs, or other figures. First state the overall relationship or interaction among variables that each visual represents. Then include any specific details from the visual that are important for understanding the results. Refer to your tables, graphs, or other figures as figure or table 1, 2, 3, etc.

More Help:

- Describe each visual in a separate paragraph. Each paragraph has two parts:
    1. The first sentence gives the general finding (see definition below) for the visual, what it indicates overall, and
    2. The following sentence(s) provides key details from the visual that are important to understanding the experiment (don't include all the details).
- Refer to your visual(s) in the written part of your Results in one of two ways:
    1. Refer to your visual(s) at the beginning of your findings, for example, "Table 1 shows that the reaction times decreased as the strength of the solution increased." "Figure 3 demonstrates that the mortality rate among riparian mammals adhered to approximately seven-year cycles." (It is also possible to use verbs such as "*lists*," "*displays*," "*describes*," etc.)
    2. Refer to your visual(s) in parentheses at the end of the of your findings. For example, "The reaction times decreased as the strength of the solution increased (Table 1)." "The mortality rate among riparian mammals adhered to approximately seven-year cycles (see Figure 3)." (Ask your teacher which format to use for parenthetical documentation.)

General Finding:

You can determine the general finding for each visual in one of two different ways:

> as a summary of all the information in the visual **OR** as a statement that focuses on the most important point that is made in the visual (important, that is, in terms of the hypothesis).

- Refer to your visual(s) in the written part of your Results in one of two ways:
    1. Refer to your visual(s) at the beginning of your findings, for example, "Table 1 shows that the reaction times decreased as the strength of the solution increased." "Figure 3 demonstrates that the mortality rate among riparian mammals adhered to approximately seven-year cycles." (It is also possible to use verbs such as "lists," "displays," "describes," etc.)
    2. Refer to your visual(s) in parentheses at the end of the of your findings. For example, "The reaction times decreased as the strength of the solution increased (Table 1)." "The mortality rate among riparian mammals adhered to approximately seven-year cycles (see Figure 3)." (Ask your teacher which format to use for parenthetical documentation.)

Step 5: Complete the Results by placing all the elements you've written in the proper order: (1) the sentence summarizing the overall data for the lab; (2) the paragraphs of word descriptions for each visual arranged in the order the visuals are presented. Remember that the Results only reports and describes what you observed and collected during your lab. The Results does not explain, discuss, or

draw conclusions.

The Results looks like this:

- Summary of overall findings of lab
- Paragraph related to visual 1
    1. Sentence of overall finding from visual 1
    2. Sentence(s) with key details from the visual 1
- Paragraph related to visual 2
    1. Sentence of overall finding from visual 2
    2. Sentence(s) with key details from the visual 2
- Paragraph related to visual 3
    1. Sentence of overall finding from visual 3
    2. Sentence(s) with key details from visual 3, etc.

SECTION THREE : Introduction

Establishing a context for the lab

Step 1: (Use your response to PreLab question 1 for this step.) Briefly describe the research problem you were given to solve. Define the problem by giving the knowns and the unknowns. Then state the research question that you used to guide the research to solve your problem. This will be the first paragraph or so of your Introduction.

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- If you are having trouble writing a good opening sentence for the lab report, you can say something like: “The problem for this lab was X…” “The problem we were asked to solve was X…”.
- As you are defining the problems, don’t just list the knowns and unknowns. Describe them in paragraph form.
- You can give your research question in the form of a question or as a statement, such as “To solve this problem, it is necessary to find Y…”.
- Be sure to make the connection between the unknowns and the research question, to show how answering the question will lead to the solution to the problem.

Step 2: (Use your response to PreLab questions 2 and 3 for this step.) In the next paragraph or two, state the scientific concept that this problem relates to. Then describe what you know about the scientific concept that is relevant to understanding and solving the problem. Note any citations you use here for References section.

More Help:

- If you are having trouble starting this paragraph, here are some suggestions: "The problem for this lab is based on Z…"; "This laboratory is about X…" ; "This lab is designed to help students learn about, observe, or investigate, X…." Or begin with a definition of the scientific concept: "X is a theory that…."
- Once you have your opening sentence, you are ready to complete the opening paragraph by telling what you know about the scientific concept. The point is to show your lab instructor that you have a good grasp of the scientific concept. Revise your response to the PreLab question by:
    - Focusing it so that it contains information about the concept that is most clearly related

to the lab problem (not everything there is to know about the concept).
    - Incorporating additional relevant information about the concept you may have learned since doing the PreLab.
    - Changing it so that the scientific concept is appropriate to the lab (this would apply if all or parts of what you wrote about the scientific concept in the Pre-Lab are wrong for this lab).
- If you have a lot to say about the scientific concept, use more than one paragraph.
- This part of the Introduction is typically written in present tense.

For more advanced labs:
If you are writing a lab report that is intended to be more like a full scientific paper, you may need to do more research using the Internet and library. With your teacher's guidance, you should search the recent scientific literature to find other research in this area of study. Summarize that research in a paragraph or so, stating what the general findings have been and using those findings to describe the current knowledge in the area (such a "review of the literature" is typical of scientific journal articles). This summary should come after your initial sentence about the scientific concept. For help with citing references, go to Citations and References in the Resources page.

Step 3: (Use your response to PreLab questions 3-5 for this step.) In a paragraph or two, present the hypothesis that emerged out of the research question. Then explain the reasoning you used, based on what you have said about the scientific concept, to arrive at the hypothesis. Finally, in a sentence or two, briefly describe the experimental procedures you used to test your hypothesis.

More Help:

- Revise your original hypothesis from the PreLab so that it is clearly stated: "The hypothesis for this lab was…"; "My hypothesis was…"; "We predicted that…"; "I hypothesized that…."
- As you are explaining the reasoning you used to come to your hypothesis, be sure to make a direct connection between the hypothesis and the scientific concept of the lab. You can also use basic scientific logic that is not specifically linked to the scientific concept.
- One way to make your explanation clearer is to use words that show causal links: *because*, *since*, *due to the fact that*, *as a result*, *therefore*, *consequently*, etc. For example, Since X happens in order to maximize energy, we hypothesized that . . .
- If your explanation is relatively long, use more than one paragraph.

SECTION FOUR : Discussion

Interpreting the results of the lab

Step 1: Write a sentence or two stating whether or not the results from the lab procedures fully support your hypothesis, do not support the hypothesis, or support the hypothesis but with certain exceptions.

More Help:

- Go back to the first part of your Introduction. Then review your findings, the data from the experiment. Make a judgment about whether or not the hypothesis has been supported. It is at this point that you, as a scientist, must be as unbiased and objective as possible.

- IWrite a sentence stating your judgment. There are three possible judgments you can make:
    1. the data support the hypothesis;
    2. the data do not support the hypothesis; or
    3. the data generally support the hypothesis but with certain exceptions (tell what those exceptions are).

    Example: "The hypothesis that X solution would increase in viscosity when solutions Y and Z were added was supported by the data."

Step 2: In a paragraph, identify specific data from your lab that led you to either support or reject your hypothesis. Refer to the visual representations of your data as evidence to back up your judgment about the hypothesis.

More Help:

- Return to the Results to identify the particular data that led you to your judgment about the hypothesis.
- Write a paragraph (or 2 if necessary) in which you present the relevant pieces of data from the lab and show how they relate to the hypothesis.
- Refer to data from specific visuals appropriately: Table 1, Figure 2, etc.

Step 3: In a paragraph or two, use your understanding of the scientific concept of this lab to explain why the results did or did not support your hypothesis. If the hypothesis from the Introduction was not fully supported, show how your understanding of the scientific concept has changed. Note any citations you use here for including in the Reference section of your report.

More Help:

In Step 2 you pointed to data that led you to your judgment about your hypothesis. Now you use your understanding of the scientific concept of the lab to explain your judgment. Whatever the relationship between the hypothesis and the results, you must provide a logical, scientific basis for it.

- Return to the scientific reasoning you used to generate your hypothesis (Step 2 of the Introduction). Use it and your understanding of the scientific concept of the lab as starting points for your explanation. Your explanation is likely to follow one of four scenarios. Choose the one that best fits your report:
    - If the results fully support your hypothesis and your reasoning in the Introduction was basically sound, then elaborate on your reasoning by showing how the science behind the experiment provides an explanation for the results.
    - If the results fully support your hypothesis but your reasoning in Introduction was not completely sound, then explain why the initial reasoning was not correct and provide a better reasoning.
    - If the results generally support the hypothesis but in a limited way, then describe those limitations (if you have not already done so) and use your reasoning as a basis for discussing why those limitations exist.
    - If the results do not support your hypothesis, then explain why not; consider (1) problems with your understanding of the lab's scientific concept; (2) problems with your reasoning, and/or (3) problems with the laboratory procedure itself (if there are problems of reliability with the lab data or if you made any changes in the lab procedure, discuss these in detail, showing specifically how they could have affected the results and how the uncertainties could have been eliminated).

Step 4: In a paragraph or two, restate the research question and present the answer your experiment

has suggested for that question. Show how the experiment has helped you to solve for the unknowns.Then restate the problem that your research was designed to solve and discuss the solution to the problem suggested by the answer to the research question.

More Help:

At this point in the lab report you return to where you started in the Introduction, the problem. The goal of the lab was to answer the research question in order to solve the problem. Now that you have presented your data and made a judgment about your hypothesis, you are ready to come full circle back to the problem.

- Go back to the research question you posed in the Introduction. The experiment you performed was designed to answer that question. If you are having trouble starting this paragraph, here are some suggestions: “The research question for this experiment was….”; “The experiment described in this report was designed to answer the question,…”; “The research reported here addressed the issue of…”.
- The research question probably grew out of the unknowns in the problem. Answer the question in such a way that you show a direct link between the answer and the unknowns.
- The solution to the problem is most likely going to center on the identification of the unknowns. State the solution to the problem and show how the solution to the problem came out of the identification of the unknowns.
- A good discussion is going to enable the reader to draw a clear line from the experimental data through the hypothesis and the answer to the research question to the solution to the problem.

Step 5: Discuss other items as appropriate, such as (1) any problems that occurred or sources of uncertainty (see below for definition) in your lab procedure that may account for any unexpected results; (2) how your solution to the problem compared with the solutions of other students in the lab and an explanation for any differences; (3) suggestions for improving the lab.

More Help:

- In science, a source of uncertainty is anything that occurs in the laboratory that could lead to uncertainty in your results. Sources of uncertainty can occur at any point in the lab, from setting up the lab to analyzing data, and they can vary from lab to lab. Return to the notes you took during the lab procedure. Look for possible sources of uncertainty in setting up the lab, calibrating instruments, and taking measurements as well as problems with the materials you are using.
- In scientific articles, the Discussion is where scientists typically compare their results to those from other similar scientific experiments. You can do something similar in your lab report. If you have compared your results with others in your lab, describe what you found and comment on any differences in the solutions to the problem: what were the differences, why there were differences, and what are the implications of the differences for the problem? Be sure to check with the lab instructor beforehand to see if it is permissible to compare results.

For more advanced labs:

- It may be useful to classify the kinds of uncertainty you have identified. Sources of uncertainty can be classified as random--those that cannot be predicted--or as systematic--those that are related to personal uncertainty, procedural uncertainty, or instrumental uncertainty.

Sources of Uncertainty:
In science, a source of uncertainty is anything that occurs in the laboratory that could

lead to uncertainty in your results. Sources of uncertainty can occur at any point in the lab, from setting up the lab to analyzing data, and they can vary from lab to lab. This is why it is so important to keep detailed notes of everything you do in the lab procedure and any problems you encounter. Try to be especially aware of any problems in setting up the lab, calibrating instruments, and taking measurements as well as problems with the materials you are using.

For advanced labs, you may want to classify the kinds of uncertainty you have identified. Sources of uncertainty can be classified as random-those that cannot be predicted-or as systematic-those that are related to personal uncertainty, procedural uncertainty, or instrumental uncertainty.

SECTION FIVE : Conclusion

Focusing on what you learned by doing the lab

Step 1: Write a paragraph summarizing what you have learned about the scientific concept of the lab from doing the lab. Back up your statement with details from your lab experience.

More Help:

- Return to the scientific concept you established in the Introduction. But instead of describing what you know about the scientific concept in the Conclusion, describe what you learned about the concept from doing the lab. For example:
  - How did solving the problem help you to learn about the concept?
  - How has your understanding of the concept improved or otherwise changed from doing the lab?
  - What specific aspects of the procedure or data contributed to your learning?
  - What difficulties did you have with the concept before doing the lab and how were those difficulties alleviated by doing the lab?
  - How might what you have learned in the lab be applicable in the future?
- Be direct in your statement of what you have learned. Don't be afraid to start out saying, "In this lab, I learned that ...." This sort of clarity will be appreciated by the reader. Elaborate on your statement with additional details about what you have learned.

Step 2: If there is anything else you have learned about from doing the lab, such as how to solve this particular problem, how to design an experiment, the kinds of the lab procedures or kinds of analyses you used, describe it in a paragraph or 2.

More Help:

- There may be more that you have learned about from the lab experience than the scientific concept of the lab. If so, write a paragraph describing it. For example:
  - What did you learn about experimental design, how to design an experiment?
  - Was there anything in the experimental procedure that you found particularly interesting to learn how to do?
  - Did you apply a procedure for analyzing data that was useful to learn about?
  - Did you learn anything about using a spreadsheet or graphing or creating other visuals?
  - Did you learn anything about writing or about science from writing the

report?

SECTION SIX : Abstract

Summarizing the lab report

Summarize each major section of the lab report--Introduction, Methods, Results, Discussion, and Conclusion--in 1 sentence each (two if a section is complex). Then string the summaries together in a block paragraph in the order the sections come in the final report.

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You can think of the Abstract as a miniature version of the whole lab report. Read each section of the report and boil it down to a sentence. This means that you need to determine the most important information in each section.

- Here are some suggestions for what to include in each sentence of the Abstract:
  - Introduction: research problem of the lab; hypothesis
  - Methods: a quick description of the procedure
  - Results: statement of the overall findings
  - Discussion: judgment about hypothesis; solution for problem
  - Conclusion: what you learned from doing the lab
- Put all these sentences together into one paragraph with the heading "Abstract."

SECTION SEVEN : Title

Capturing the essence of the report

Write a title that captures what is important about the lab, including the scientific concept the lab is about and variables involved, the procedure, or anything else that is important to understanding what this report is about.

More Help:

You write the title after you have written the other parts of the report, because the title reduces the report down to its essence, and it's not until you finish writing the report that you are able to identify what that essence is. A good title very efficiently tells the reader what the report is about.

Hints:

- If you are having trouble writing a title, try this approach. List the keywords related to the report: the scientific concept of the lab, the kind of procedure you used, names of key materials, what you experimented on, etc. Then write a title that describes the lab using the most important of these keywords.
- A title should use the fewest possible words to adequately describe the content of the report.
- A title should be as specific as possible. Specify the primary focus of the experiment and procedures used, including the scientific names of chemicals, animals, etc.
- Do not write the title as a complete sentence, with a subject and a verb. Titles are labels, not sentences.

- Do not use catchy titles. This is not an English paper or an editorial.
- Find the right balance for the length of the title: not so short that it doesn't communicate what the report is about but not so long that it rambles on for more than a line.

SECTION EIGHT : References

Acknowledging sources of information

If it is appropriate for your lab report, put a References section at the end. List all the sources you referred to in writing the report, such as the lab manual, a textbook, a course packet, or scientific articles. Be sure to use the proper form of documentation for the scientific field you are working in (ask your lab instructor if you are not sure). See Citations and References in the web version of this document.

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- Different scientific fields use somewhat different styles for documenting sources in the References. For example, in chemistry you would follow the American Chemical Society (ACS) style. In biology, it would be the Council of Biological Editors (CBE) style. Check to see which style is appropriate for your class.
- You can find information about various documentation styles at Citations and References in the web version of this document.

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