

IMPROVING YOUR LAB NOTEBOOK

Improving your Introduction

- *successfully establishes the context (the scientific concept) of the lab*

To establish the context of the lab you need to do two things:

1. state what the lab is about, that is, what scientific concept (theory, principle, law, etc.) or lab procedure you are supposed to be learning about by doing the lab. You should do this briefly, in a sentence or two. If you are having trouble writing the opening sentence of the report, you can try something like: "This lab focuses on 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..."
2. give the necessary background for the scientific concept or lab procedure by telling what you know about it (the main references you can use are the lab manual, the textbook, lecture notes, and other sources recommended by the lab manual or lab instructor; in more advanced labs you may also be expected to cite the findings of previous scientific studies related to the lab). In relatively simple labs you can do this in a paragraph following the initial statement of the learning context. But in more complex labs, the background may require more paragraphs.

- *effectively presents the objectives and purpose of the lab*

In a paragraph, or more if you need it, write out the objectives of the lab in sentence form and then describe the purpose of the lab: what it is that accomplishing the objectives will help you learn about the scientific context of the lab (the scientific concept or procedure of the lab).

1. The objectives are what it is you are supposed to accomplish in the experimental procedure itself. An objective, therefore, is usually presented in terms of a specific verb that describes what you are supposed to be doing in the lab, such as to measure, to analyze, to determine, to test etc. Often, the objectives for the lab are given in the lab sheet. If you are having trouble phrasing the sentence about objectives, try something like: "The main objectives of this lab were to..."; "In this lab we were to..."
2. The purpose of the lab is different in significant ways from its objectives. Purpose provides the wider view; it answers the "why" question, why you are doing the lab in the first place: how achieving the objectives of the lab lead to learning about the scientific concept or lab procedure. Instead of focusing just on the specific actions of the experimental procedure, purpose looks at the experimental procedure within the context of what you are supposed to be learning.

If you are having trouble starting the sentence about the purpose of the lab, try saying something like this: "The objectives of this lab enabled me to learn about X by..."; "Performing these objectives helped me to understand X by...." To improve this part of the introduction, go back to what you have written about the scientific concept and look for a link between it and the activities you are expected to perform in the lab: what specifically about the scientific concept or lab procedure were these activities designed to teach you?

- *presents interesting questions or issues related to the lab*

The goal of this lab is to help you understand more about the scientific concept of the lab or the procedures you are working with in the lab. One thing that drives this understanding is questions that you raise about the concept and procedures. It is out of these questions that issues related to the lab emerge.

If you did not present any issues at this point in the Introduction, you can improve this part of the Introduction by thinking of some questions about the lab that could be interesting or useful to learn about. Review what you are supposed to be learning about by doing the lab. Look for things that you don't understand or would like to know more about. If you did present some questions or issues, try to make them more interesting, more useful, or clearer. You can present your issues or questions in sentence form or list them in bullets.

Improving your Procedure

A good Procedure section describes what you did in the lab in a way that is easy to understand and detailed enough to be repeated. To make your Procedure better, follow these guidelines:

- If your Procedures is not easy to follow, you may ask someone to read it. Ask him or her to identify places in the procedure that are not clear and then revise those places for greater clarity. It may also be helpful to include words that help the reader follow the process of the experiment: step 1, step 2, step 3; first, then, finally; first, second, third; after, next, later, following; etc.
- If your Procedures is difficult to follow because it is long and complicated, then consider dividing it into separate parts, each with a subheading (such as Lab Set-Up, Lab Procedure, etc.) or, if there were multiple procedures, you may describe them in separate sections.

- If you need to add more detail to your Procedures, go back to the lab sheet and to the notes you or a lab partner took during the procedure and use them to help you remember what you did in the lab.

Improving your Results Section

- *opens with a sentence or two describing the main finding(s) of the lab*

Results sections typically begin with a brief summary of the findings. Such a statement is typically a sentence or two. This summary acts as the opening sentence for the Results. If you had trouble getting the first sentence started, here are some possibilities: "The results of the lab show that ..."; "The data from the lab investigation demonstrates that..."

- *presents visuals clearly and accurately*

One of the main problems with visuals (tables, drawings, etc.) is lack of clarity. You may have chosen a form of visual that does not represent the data clearly.

Another problem with visuals can be ascribed to lack of accuracy. Visuals are accurate when they correctly represent the data from the lab. If there is a problem with accuracy, you should check three points at which accuracy could be jeopardized: (1) you may have recorded the raw data from the procedure incorrectly; (2) you may have entered the raw data onto the spread sheet incorrectly; and (3) you may have made careless errors in the format of the visuals.

- *presents verbal findings clearly and with sufficient support*

The presentation of findings in words should be ordered according the order of the visuals, each visual being described in words. Each description should include a sentence or so summarizing the visual and then any details from the visual pertinent to the data from that visual. To make the verbal part of your Results better, follow this general outline:

- Summary of overall findings of lab
- Description of visual 1
 - Sentence of overall finding from visual 1
 - Sentence(s) with key details from the visual 1
- Description of visual 2
 - Sentence of overall finding from visual 2
 - Sentence(s) with key details from the visual 2
- Description of visual 3
 - Sentence of overall finding from visual 3
 - Sentence(s) with key details from the visual 3
 - Etc.
- *successfully integrates verbal and visual representations*

The verbal representation of each visual should refer explicitly to the visual ("Table 1," "Figure 2," etc.). You should create the sense that the visual and the word representations of data are working together. The primary way of doing that is to cite the visuals in your verbal findings. If you had trouble integrating the verbal and the visuals, be sure you have, at a minimum, a reference to the visual in the sentence in which you describe the overall finding of the visual.

Another potential problem in successfully integrating the visual and verbal elements of the Results is that the verbal descriptions may repeat all the data from the visuals. There is no need to repeat all the data; it's already in the visual. The job of the verbal description is to highlight what is important in the data, particularly in terms of the scientific concept or procedure in the lab. So if you have simply described all the data from a visual, try to determine what data points are most important for the reader to focus on and describe those data points.

Improving your Safety Hazards

A Material Safety Data Sheet (MSDS) is designed to provide both workers and emergency personnel with the proper procedures for handling or working with a particular substance. MSDS's include information such as physical data (melting point, boiling point, flash point etc.), toxicity, health effects, first aid, reactivity, storage, disposal, protective equipment, and spill/leak procedures. These are of particular use if a spill or other accident occurs.

The Safety Hazards section of the lab notebook should address only the health effects section of the MSDS sheet. An MSDS sheet for any chemical used in the lab should be referenced and a summary of the health effects of that chemical should be included in the lab notebook. Once recorded, if that chemical is used in another lab later on in the year, you only need to reference the previous lab's health effects.

Improving your Discussion

- *opens with an explanation of how the findings link to the context of the lab*

The Discussion should start with a paragraph that relates what you have done in the lab to what you are supposed to be learning by doing the lab. If you had trouble with this part of the report, go back to the Introduction where you establish the context (scientific concept or lab procedure you are supposed to be learning about) of the lab. Refer specifically to the findings from your Results to explain what the findings mean in relation to the scientific concept. In other words, discuss the connection between the evidence you collected and what you were supposed to be learning about by doing the lab.

Here are some questions to help you do this part of the Discussion better:

- What is the connection between the findings of the lab and the scientific concept or procedure of the lab?
- What implications do the findings suggest about the concept or procedure?
- How do the findings relate to your description of what you already knew about the concept or procedure in the first paragraph of the Introduction?
- Use the answers to these questions to explain the relationship between findings and the concept or procedure.

- *addresses questions and issues related to lab and discusses answers to these questions*

It is at this point in the report that you return to the questions or issues you raised in the Introduction. Use specific references to your lab observations and procedures to discuss what you have found concerning the questions or issues. Also discuss the importance of these questions or issues as they relate to the scientific concept or lab procedure.

Return to the end of the Introduction where you raised the questions to guide your learning. Identify any of those questions that your research provided answers for, even partial answers. These are the ones you can discuss in this section of the report. Consider each question separately, unless some questions are better grouped together. Restate the question or issue and present what you think is an answer to it. Then explain how you came to the answer. This is where you should refer to specific findings or other observations from the laboratory procedure.

If you are not sure of an answer, put in any qualifiers you think are appropriate. You can say that you think the answer is tentative.

- *sufficiently addresses other issues pertinent to lab*

Other issues that may be appropriate to address are (1) questions or issues that remain unanswered and why; (2) problems or sources of uncertainty in your lab methods that may have led you to unclear answers or unexpected results; (3) how your findings compare to the findings of other students in the lab and an explanation for any differences (check with the lab instructor to make sure this is permissible); (4) what further investigations you would do in order to gather more information; (5) suggestions for improving the lab.

Improving your Conclusion

This section is probably the most important one of your report and the main reason you are writing the report. All previous sections are just the foundation, but this section is the real measure of what you have learned from this experiment and of your writing skills.

Questions to discuss for a well-rounded Conclusion section might include:

- Have you answered the question posed?
- What does the data suggest?
- If you ran into trouble, why?
- What could be done differently in order to improve the result, to lead you to a more definitive answer to the question?
- What new questions have been posed by this experiment?

A good way to start writing a conclusion/discussion is to consider the purpose of the experiment. Consider the data, identify patterns in the data, and then discuss your results.

- *present the conclusions you draw from the results.*

All conclusions should be clearly stated and supported with evidence. Cite specific results and observations from the experiment and tie them to your conclusions. Summarize reasons for any disagreement between your results and the

expected results. Recommend ways to correct problems that may have led to discrepancies or bad data points. Recommend any practical way of improving the experiment.

This section provides the opportunity to explain and interpret the results. In this section, you will discuss the significance of the results that were obtained (i.e. why were they important). You can also compare results between materials that were prepared differently. If there were any anomalies in the data or parts of the experiment were unsuccessful, possible causes (and solutions) should be discussed here. If you would like to propose any suggestions for future work, they can be included here.

- ***convincingly describes what has been learned by doing the lab***

A good Conclusion takes you back to the larger purpose of the lab as stated in the Introduction: to learn something about the scientific concept, the primary reason for doing the lab. The Conclusion is your opportunity to show your lab instructor what you learned by doing the lab and writing the lab report.

You can improve your Conclusion first by making a clearer statement of what you learned. Go back to the purpose of the lab as you presented it in your Introduction. You are supposed to learn something about a scientific concept or lab procedure. If you are not sure if you have stated what you have learned directly enough, read your first paragraph to see if your reader would have any doubt about what you have learned. If there is any doubt, you may begin the paragraph by saying something like, "In this lab, I learned that"

Simply saying you learned something is not necessarily going to convince the reader that you actually did learn it. Demonstrate that you did indeed learn what you claimed to have learned by adding more details to provide an elaboration on the basic statement. Read over the Results and Discussion and jot down some notes for further details on what you have learned. Look carefully at the statement of what you have learned and underline any words or phrases that you could "unpack," explain in more detail. Use this brainstorming as a way of helping you to find details that make your Conclusion more convincing.

Improving the Presentation of your Notebook

- ***you should always write in indelible ink***

Things gets spilled on notebooks, they get wet, and all your notes should be written as if they are for posterity. Never try to erase; to correct something, simply cross out neatly with a line or two, not with a heavy blob of lines. One benefits from one's mistakes and while you can acknowledge the mistake by a neat cross out, it is not helpful to lose it completely. You'd be surprised how often you'd really like to know which settings on a piece of equipment or which solutions didn't get used. Finally, never use white-out. White-out flakes off and makes a mess, and, like ripped out pages, indicates that you are attempting to hide something.

- ***never tear pages out of your notebook***

To those who don't know what a fine, honest person you are, missing pages may be construed as dishonesty--that you are trying to hide embarrassing data that contradict your pet theory, for instance. If you are ever applying for a patent on something you've developed, a competitor could use those missing pages to argue that you didn't really do the work and are trying to hide evidence.

Overall Aims of the Notebook: The student...

- ***has successfully learned what the lab is designed to teach***

This is, of course, the purpose for doing the lab, to learn something about the science of the course you are taking. Reading your lab report gives your instructor a good idea of how well you have achieved this all-important aim. It's your job in the lab report to represent as fairly as you can what you have learned.

What you have learned is indicated in the report, especially the Introduction and the Conclusion. You should begin the Introduction by setting up the learning context, the scientific concept or lab procedure, you are supposed to be learning about by doing the lab. Be sure that the learning context you establish in the Introduction does indeed match the learning goal from the lab manual or handout.

You can improve this part of the report also by (1) expressing more clearly what you are supposed to be learning about and (2) providing a clearer or fuller description of what you already know about the learning context. In addition, check your designation of the purpose of the lab in the Introduction. Be sure that it explicitly and clearly makes the connection between the objectives of the procedure and what you are supposed to be learning.

The other key part of the report you should review is the Conclusion. This is where you make your strongest case for what you learned in doing the lab. You may be able to improve the Conclusion by rewriting the statement of what you have learned, rewording it so that it is clearer to the reader. You could also enhance the rest of the Conclusion by adding more details concerning what you have learned (see treatment of Conclusion above). Remember, your job is to convince your reader that you have achieved this aim, and this is the section of the report in which you do that directly.

- *accurately analyzes data for lab findings*

There are two ways of looking at this aim, depending on the kind of lab you are in. In some labs, there is a "right answer," a specific unknown or standard measurement you are expected to find. In these cases, the emphasis of the aim is on "expected outcomes." That is, your laboratory procedure is expected to yield certain results and, to a certain extent, the quality of your work depends on whether or not you attain those results.

In other kinds of labs, there may be no established outcome for the procedure, or it may be that doing the procedure in a scientifically sound way is more important than the particular answer you get.

In both kinds of labs, the places where you need to focus your efforts on improvement are Methods and Results. If you need to have the right answer, then you should revisit your lab notebook to search out errors in recording data and transcribing data to a spread sheet and in any calculations you have done. You must rewrite your report accordingly.

But if your aim is to demonstrate that your procedures are sound and that they legitimately lead to your results, then look at these sections of the report. Is your procedure described clearly enough? Are your results presented in sufficient detail? The point is to demonstrate that there is a clear relationship between procedure and outcomes.

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