The Hixon Writing Center at Caltech

Lab Reports to Document and Analyze Experiments

This handout offers students an introduction to laboratory or technical reports used in academia and industry to communicate experimental methods and results. Students working with this writing genre as part of a course assignment may have guidelines or requirements that differ from those described here.

Introduction

Laboratory or *technical reports* are documents that methodically describe experiments performed in academia and industry. These reports have similar structures and content as journal articles, with particular emphasis on the precise details of the methods, results, and immediate implications, and are as long as necessary to communicate these details. Unlike journal articles, however, lab reports are not prepared with the external science community in mind. Lab reports are often written for audiences internal to a group, company, or organization, where all readers are closely involved with the experiments or the implications of the results.

Purpose

Lab reports are essential tools that scientists, engineers, managers, and corporate customers use to analyze and replicate experiments, identify and solve problems, and drive new product and technology decisions. Students often write lab reports to document and analyze experiments as part of a course. This exercise provides valuable practice and feedback in preparation for writing future reports during their careers. Scientists and engineers write reports to allow for exact recreation of an apparatus, protocol, and subsequent results by others. Therefore, the reports must be sufficiently detailed and absolutely accurate; writers must provide correct results and figures, precise units and measurements, and specific statistical significance (e.g. error or confidence intervals). This ability to exactly replicate experimental conditions and outcomes helps scientists and engineers assess the strengths and weaknesses of their protocols.

Lab Report Content, Rhetoric, and Style

Lab and technical reports begin by orienting the reader to the motivation and objectives of the experiment, then give a step-by-step explanation of the theory, apparatus, and methods used. This information is followed by quantitative and visual reporting of results and a discussion of the immediate implications and recommendations resulting from those experimental analyses. It is good report writing practice to (1) organize content in a predictable structure, (2) tailor the content to match the audience, (3) use professional and accessible language, and (4) communicate technical information using appropriate figures.

1. Organize the report for easy navigation.

In the same way that engineers follow detailed specifications in their research to ensure consistent performance, they must also adhere to specific writing guidelines to ensure consistency across a discourse. Writers must strictly follow standards for report content, organizational structure, and style defined by a particular organization, department, or task. Despite differences in their presentation, most reports employ easy-to-navigate structure and are written in clear and precise language. The sections of a report mimic those of a manuscript but include emphasis or additions required by the course, lab, project group, or company. In general, a report includes the following elements:

- A title page with a powerful title that highlights of purpose or major result. A strong title is concise (10-15 words) and uses descriptive terms to identify the core content of the report. The title page also includes a list of the people who performed the work, the class/lab group/project under which the work was performed, the date of the experiments, and the date the report is filed.
- An abstract that is a standalone summary of the contents contained in the report. *See the Hixon Writing Center's handout on Writing Effective Abstracts on the Resources page of the website for more information about writing abstracts.*
- A succinct introduction that provides only the background necessary to explain the motivation for conducting the experiments and the experimental history on which the work builds.
- A section describing important theories, assumptions, or computational analysis (if applicable).
- For reports focusing on a novel device, apparatus, or experimental setup, a detailed illustration with technical specifications of the equipment that was built, tested, or used to conduct the experiments (*see Figure 1*).
- Methods described in a sufficient level of detail and precision to allow for exact replication. For example, the author should describe what techniques were used to gather data and under what conditions, but should not describe how to operate the devices or tools used to do so (unless they were built *de novo* as part of the experimental objectives).
- A description of the results in the form of both qualitative observations and quantitative outcomes. Importantly, this section can also document any negative results obtained. Here, visual presentation of results should be used when possible to facilitate communication to the varied technical levels of readers.
- A discussion of those results, including postulation to explain any inconsistencies, and the implications of the measured outcomes. Reports can also detail new experimental directions to be pursued.
- References of cited literature or other methods used.
- Appendices for any additional information (instead of a Supplemental Information section found in research manuscripts).

2. Tailor content for the audience and purpose.

Students write lab reports for courses as practice for communicating experimental results as professionals. Their audience is made up of *professors, instructors, teaching assistants, and their peers* and should be written in language accessible to them. Students should make sure to follow report guidelines on organization, content, and formatting if provided in their course.

Academic scientists and engineers create internal lab reports, alternatively called *protocols,* to guide *future students or researchers* through standard experiments and ensure reproducibility. These reports include important details like tried-yet-unsuccessful attempts and ineffective reagents to prevent repeated failures. In an industry research setting, reports allow scientists and engineers to optimize

product quality and yield, track protocol efficiency and cost, and troubleshoot any problems that might arise. Reports can help to identify points in a manufacturing method which are most likely to cause problems with a product, outline effective short-term solutions, systematically determine root causes, and identify efficient paths for corrective action.

In a report written for *other scientists and engineers*, it may be helpful to expand the methods section with a high level of granularity to detail any tips, tricks, or potential pitfalls that are relevant to the specific resources available to lab personnel. For example, the methods may point out a specific protocol step where there is high risk of product contamination due to limitations of the lab's existing sterile environment and advise the use to take particular care.

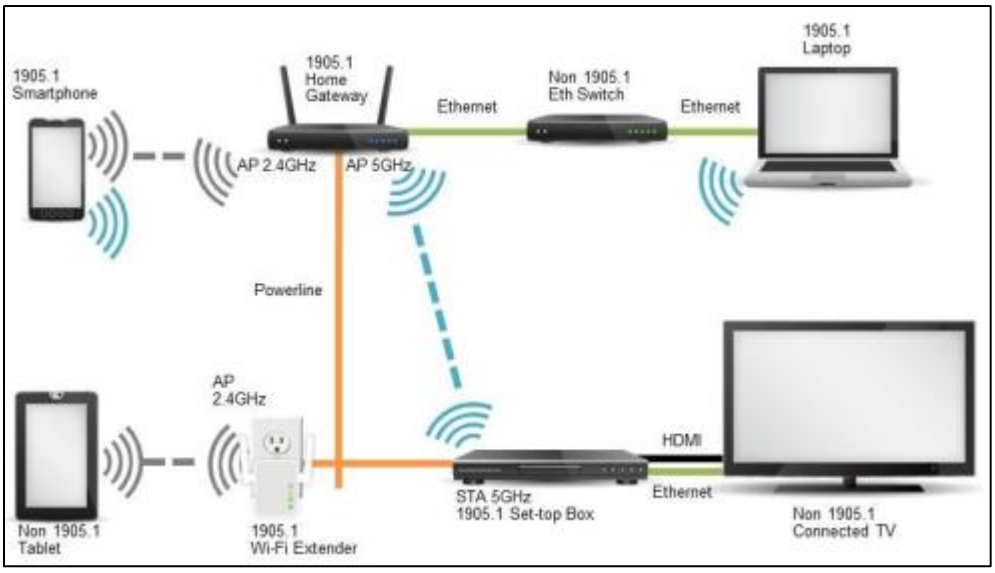

Figure 1 A detailed technical illustration of the IEEE 1905.1 standard home network architecture, complete with device types, connections, and processor speeds. This type of information would be present in the methods section of a technical report on the 1905.1 layer architecture.

Alternatively, scientists and engineers can communicate directly with *management* through lab and technical reports. A report's detailed and usually quantitative account of process outcomes guides management and drives project decisions, particularly in industry. These documents are used to communicate the results of feasibility studies for new project directions, manufacturing quality control tests, and cost analyses. Managers, who might be intimately knowledgeable about the project but less familiar with technical details (specs and protocols), may prefer reports that condense the methods and emphasize discussion of major results. Instead of grouping all results into a single section, reports can use additional descriptive sub-headers to organize core findings. For example, a lab report for management on scaling a chemical synthesis process might discuss results under sub-headers like, "Addition of new inhibitor molecule improves yield by 20%" or "Increased synthesis scale decreases total production costs by $1/mg." These sub-headers allow for easy navigation and help efficiently convey the major messages in which the target audience is most interested.

Management audiences require a thorough discussion of results and their implications in order to communicate the findings to *other project managers, investors, and customers*. Managers use an engineer's discussion of the experiment's implications and significance to drive manufacturing changes in scale, quality control, and new product directions. They can also use reports to showcase to potential investors a more effective method or to explain to customers the source of a product flaw in explaining a delivery delay.

Lab and technical reports are formulaic documents; groups often create them for many different protocols or experiments and use identical formatting and content guidelines. Courses and research groups, both in academia and in industry, may have their own guide or template for creating internal reports to ensure consistency across documents and projects. Writers should follow their organization's guides, templates, or handbooks exactly when preparing their reports.

3. Write in a professional and accessible style.

The style of a report is similar to that of a manuscript: the tone is professional, using active voice and present tense whenever possible. A professional tone is captured in the following example: "We prepared samples identically and immediately prior to data collection," has an appropriate tone for a report, whereas "Nothing was different between samples," does not. In some contexts, writers use the past tense in the methods section, but only to describe steps or events completed in the past. Sentences are direct and concise to improve readability. In industry, especially for management readership, reports are moving towards very accessible language (first person, active voice) and place major emphasis on using figures and images to convey information.

4. Use appropriate figures to help communicate trends and differences in data.

The rules or guidelines for communicating data using figures and illustrations may vary dramatically from company to company or group to group. It is important to locate models and ask for guidelines in order to emulate accepted best practices. Students writing lab reports for a course should refer to course lab manuals or the instructor's instructions but expect to adapt their report style once they have moved beyond the classroom. While there are many strategies for creating effective figures, this section offers only a concise description of a few shared best practices for visual communication.

Many lab or technical reports compare experimental outcomes to a gold standard, a negative control, and an array of different experimental conditions. Figures make it easier to identify patterns and trends in the data, but it is the author's responsibility to explain which patterns are significant and why. Toward this goal, reported data is frequently quantitative and is accompanied by the appropriate statistical analyses to objectively identify significant differences. While these data can be reported in the text or in a table, it is often more effective to present them in a figure or graph. *See the Hixon Writing Center website for more resources: https://writing.caltech.edu/resources*

The data for a figure should be restricted to just what it is necessary to convincingly communicate the message. Similarly, the visual presentation of the data should be kept simple: adhere to black and white formats whenever possible and avoid embellishments of unnecessary color, lines and arrows, or artificial graph dimensions. This "visual noise" obscures the data and the author's desired message. Units of measurement should be consistent across all datasets presented in the same figure. All figures should be accompanied by a succinct caption that enables the reader to understand the figure without reading the rest of the text body. Readers from a varied audience will be better able to understand the key findings and messages in a report through straightforward figures and their captions.

Checklist

- ❑ Does the report communicate the purpose of the experiment?
- ❑ Does the background information provide sufficient context for the research such that the reader understands the purpose and motivation of the work?
- ❑ Are the research questions clearly stated and do the results allow the authors to answer them?
- ❑ Does the author use figures to describe the apparatus (if applicable) and important results?

- ❑ Are the types of graphs or figures appropriate for the type of data being presented?
- ❑ Does the report discuss why these experiments were performed and not others? Does the report lay out the strengths of the approach?
- ❑ Does the report identify the limitations of the experiment (be they related to the apparatus, protocol, or method)?
- ❑ Are the immediate consequences or implications of the results discussed?
- ❑ Is the report understandable by the target audience?
- ❑ Is the report written in active voice and present tense when possible?
- ❑ Does the report precisely follow all guidelines and models for content and format established by the specific lab in which the report is being written?

Further Resources

Hixon Writing Center resources for related writing genres and communication techniques:

Writing Effective Abstracts

https://writing.caltech.edu/resources/abstracts

Visual Representation of Data *(Coming soon!)*

https://writing.caltech.edu/resources

Caltech academic report and figure guidelines for undergraduates participating in Summer Undergraduate Research Fellowships (SURFs) or enrolled in laboratory courses:

SURF Final Report Guidelines:

https://sfp.caltech.edu/students/summer_requirements/final_report

Caltech Chemistry 3X Figure Guidelines and Annotated Figure Examples:

https://writing.caltech.edu/documents/53-chemistry_3x_figure_guides_caltech_spring_2017.pdf

Caltech Physics 3 Lab Notebook Guidelines:

http://pmaweb.caltech.edu/~phy003/notebooks/notebooks.html

Guidelines for writing technical reports provided by NASA's Scientific and Technical Information (STI) Program whose objective is to disseminate aeronautics and space science research. While these guides are tailored to NASA employees, they provide a thorough description of the different sections of technical reports.

NASA Publication Guide for Authors

https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20150013303.pdf

NASA STI Report Series Word Template (.doc)

https://www.sti.nasa.gov/temparial.doc

Works Consulted

We consulted a number of works on this topic to create this handout, and you'll find their references here. This is not an exhaustive list of all works on this topic, and we encourage you to seek out

additional resources as needed. This citation guide is in MLA format, and it is only a citation model if you are also writing in MLA style.

Knisely, Charles and Knisely, Karin. *Engineering Communication.* Stamford: Cengage Learning, 2015.

Irish, Robert. *Writing in Engineering.* Oxford University Press, 2015.

Want to talk to someone about the information in this handout or how to apply it to your own writing? Make an appointment to come into the HWC and talk with a professional or peer tutor: writing.caltech.edu/tutoring