Guidelines for writing scientific reports

"To present a scientific subject in an attractive and stimulating manner is an artistic task, similar to that of a novelist or even a dramatic writer."
Max Born

Goal of writing a report

Over the past weeks, you have been involved in scientific research. You have learned something new and might have obtained results which have not been known before. Those obtained results might initiate new research questions or might lead to a product used in daily life. But how are others going to know about your findings and gained insights?
Scientific research does not only comprise of conducted experiments, but also of writing reports about those experiments. The written report allows the researcher to show the data to the scientific community and facilitates a platform to obtain publicity and fame. Being able to produce well-written reports, therefore, is of great importance to you to make a good impression and stand-out when you apply for a job at a university or company.
Writing is a skill that comprehends a very personal component, it reports the findings and interpretation of an individuum. Nevertheless, although writing style and preferences are person-dependent, there is a distinct structure and logic order in scientific literature, which you can learn. Here, we provide you information on the structure of scientific reports, which apply to basic lab reports and ground-breaking scientific articles, alike. Furthermore, we offer you guidance in scientific writing within the research practicals with the intent to train and improve this important skill. At the end of this course, we expect you to be able to produce a well-structured and well-written scientific report. We are looking forward to read this. Have fun writing!

Structure of a scientific report

The goal of a scientific report is to concisely document the work in sufficient detail so that your reader can follow your reasoning and validate the conclusions you drew. Therefore, a scientific report follows a distinct structure and organization comprising six mandatory components in the following order; title and abstract, introduction, method, results, discussion, and conclusion. These six components will be described in more detail below:

- **Title & abstract**
  When readers pick up your report, the title and the abstract are the first things they read. As such, title and abstract fulfil the purpose of promoting your work and matching the readers interest to your report. Title and abstract should, however, be the last pieces that the writer writes to guarantee that the title and abstract accurately fit to the body text.
  The title of scientific literature should state the aim of the described work clearly and informative and should be as specific as possible, while still describing the full range of the work in a minimal amount of words (on average ~ 11 words).
  An abstract is a concise, self-contained summary of the report that covers one or two sentences on the motivation for the work done, the addressed research question, a description of the used method, the results and the implications of the work. The abstract should be fully understandable by peers without prior knowledge about the research.

Typically, an abstract is restricted to 150-200 words (depending on journal type) and does not contain any references. Hence, words must be chosen very carefully.

- **Introduction**

  In the introduction, the authors should inform the reader what the paper is about and why the studied subject is important. Typically, a top-down approach is used in which the reader is provided with relevant background information on the research field and its scientific significance. Followed by a more specific research question or challenge point that is addressed in this report. Taken together, we can summarize the three parts of the introduction as topic, problem, solution (for engineering); or topic, knowledge gap, explanation (for science).

  Common questions that are set out to be answered in the introduction are:

  - *What is the field of work and what has already been done?*
  - *What is the research question of this report and why is this important?*
  - *What are the experimental principles and methods used to answer this question?*
  - *What can be learned from the results?*

  Common pitfalls in introduction writing include providing unnecessary background information, overstating the importance of the work or failing to make the research question clear.

  Typically, an introduction is two to three times longer than the abstract. Please refer to relevant scientific sources when giving relevant background information and your problem statement or knowledge gap.

- **Method (Theory, Materials and Methods)**

  This section describes how the results were obtained and generated and is used more broadly then a description of the experimental method. The theory section describes the theory needed to understand and interpret the experiments or the development of a theory described in the report, including necessary equations and explanations of symbols. The materials and methods used in the experiment are described in an independent section and allow the reader to reproduce the results and judge the validity of the conclusions. As such, the experimental methods might include the description of a specific experimental set-up or design (preferably with an informative sketch), and/or the description of a modeling tool. Further, the method section should include a justification of the experimental methods used, including a description of the accuracy of the measurement.

  Try to make the method section as informative as you can for the reader, this usually requires a logical structure of this section and not a chronological organization.

  Common questions that should be answered in the method section, are:

  - *What experimental method has been used?*
  - *How are the experiments taken out and is that statistically valid?*
  - *Why has this method been chosen to answer the research question?*

  Please be as thorough and detailed as possible in the method section, without expounding beyond the research topic. Common pitfalls in the method section are the inclusion of results, of unnecessary details or a chronological listing of the experimental approach.

- **Results and discussion**

  The results and discussion section contains a presentation of the obtained data, commonly quantified and presented in tables and/or graphs. Tables present the data directly and are

preferred when the exact numerical values of the data are needed. Graphs are a visual representation of data sets and a powerful tool to convey complex data clearly and effectively. They employ the magnificent power of the human brain to recognize visual and spatial patterns. Because of the importance of graphs and their broad application, multiple books have been written about creating them. Here, we want to provide you the most important guidelines:

- Choose the data set that represents the message you want to convey. Be careful, the data should represent your findings fully, including anomalies. It is unethical to "cherry-pick" a data set to make it fit a hypothesis or explanation, and it could bring you in big trouble.
- Pick a graph style that supports your message. Graphs should be as simple and informative as possible.
- Represent data as clear as possible, including a description, a number, a unit and an uncertainty estimate. Error bars and scale bars should be implemented and defined. Axes should contain a symbol and a unit.
- Data points should not be removed from a data set.
- Make your graphs as clear and concise as possible, it should be interpretable on its own. A quick glance should allow the reader to discriminate every data point and fit, even when your report is printed in black and white. You cannot fix bad data with a good graph!
- Use the accompanying caption to clarify every element of the graph. The title of the graph is represented in the caption alone.

A well-written text with poor graphs will not be evaluated as a high quality report, so graphs are really worth a great effort!

The discussion explains the data and argues how the data answers the posed research question(s). The combination of results and discussion facilitate an explanation on what the reader should see in the graphs, whether and why the data were expected, and what the shortcomings of the data are.

As such, the following questions are to be answered in the result and discussion section:

- *Are the graphs accurately representing the data set? Is uncertainty properly assessed?*
- *How do those data answer the research question?*
- *How do your results compare to other people's work (refer to scientific papers), or to expected outcomes? If your results do not meet expectations, please explain the difference.*
- *How widely applicable are these results? What are the boundary conditions of the experiment?*

Some common pitfalls you should avoid for the results and discussion section are the lack of organizational structure, i.e. presenting results without discussion, posing a discussion unrelated to the obtained results, ignoring data that does not fit the hypothesis or presenting the data in chronological rather than logical order.

- **Conclusion**

  The conclusion concisely provides the key message(s) the authors want to convey. The conclusion should allow readers that did not read the full report to understand the answers to the main research question set out in the introduction and the implications of those findings. The essence is to provide the most general claims that can be supported by the evidence and a future perspective on the scientific work.

  Questions to be answered in this section are:

- *What can be learned from the work done?*
- *What impact does this work have on the research field?*
- *What further research directions does this work facilitate?*

Some common pitfalls in the conclusion comprehend the introduction of new evidence or arguments, a repetition of background information provided before or failing to address all research questions.

- **References**

No scientific report is complete without a proper reference list. For a second-year practical, you are expected to find some trustworthy scientific literature yourselves through web of science or Scopus. Process the information you found in your report, for example in the introduction and discussion. Use an existing reference style (output style) to format your references. Examples or well-known and well-described output styles are APA7 (author-year style) and IEEEE (numeric style).

Pitfalls include incomplete title descriptions in the reference list, inconsistent reference formats, mis ordering of the references. APA7 has a list that is ordered alphabetically by last name first author, IEEEE orders the reference by first in-text appearance (first reference is always [1], etc).

We advise you to write your scientific report according to the provided structure above. Nevertheless, you will see that in scientific literature sometimes additional components are added to or segregated from the standard organization when the nature of that work demanded a differentiation. But, for now, structuring your paper according to the most commonly used standard organization will facilitate your writing job and the readability of your report.

Writing style and language conventions

Scientific reports intend to describe a complex subject as clearly as possible to knowledgeable peers. To match the content of the report to the readers prior knowledge or the scope of a journal is a task many scientists struggle with, students and professors alike. For the research practicals, we expect you to write a report in English or Dutch that can be easily read by one of your fellow students. In order to do so, key is to pay attention to good writing style which can be defined as the formulation of clear and accurate sentences, writing a clearly defined message per paragraph and providing an overall organized structure to your body text. Though, what a good writing style exactly comprises, is rather person-dependent and sometimes sparks argumentations among scientists. The best way to explore what you define as good writing style, is by reading well-written scientific papers and paying attention to what you like about that particular writing style and approach. Go ahead and explore some of your favorite papers, what do you like about the writing and what not?

- **Writing in scientific style**

Overall, the most valued concepts to scientific writing are accuracy, precision, clarity, concision and grace of the written wording. Here, accuracy means that claims made in the report are justified by the provided information and, hence, verifiable. Precision comprises that the meaning and intention of the written words are comprehended by the reader. Clarity requires that the written text is easily understood and avoids the usage of unnecessary complicated jargon. Concise writing can be understood as omitting needless words, which is

highly appreciated by the reader since it saves him/her valuable time. Grace is the mastery of scientific writing style and rarely achieved. It comprises writing with elegance and fluency without the loss of accurate, precise, clear and concise wording. Are these concepts you found and appreciated in your favorite papers as well?

- **Writing conventions**

Lastly, there are many conventions that you are supposed to follow but are rarely written out in scientific literature. Here, we aim to provide you with some of those writing conventions:

- Each paragraph focusses on one topic. The Hamburger model to reconstruct a paragraph might be very useful and comprises: an introduction of the topic with one sentence, followed by supporting sentences and finalize with a concluding sentence.
- Write in your own voice and try to implement simple and professional wording to increase the readability and clarity of your report. Everything you write should support the main message and highlight its context.
- Be consistent in wording and style, when a term is introduced then use it throughout the report. Also, when there is referred to a certain section or graph, be exact and unambiguous (Figure 1 shows…, Section 2 introduced…., as can be seen in Figure 3).
- Citations are required at any statement that is not derived logically from the current body text and should only comprise published literature, i.e. original papers and textbooks, not the manual of the research practicum.
- Use English tenses appropriately. The most widely used tenses in scientific writing are:
    1. *Simple past (The experiment used): describe events that happened in the past and have finished. This tense is mostly used to describe the results.*
    2. *Simple present (Equation 1 describes…): covers general statements and is frequently used in the introduction.*
    3. *Simple future (These findings will allow us to…): implies future directions and happenings, mostly used in the conclusion section.*
    4. *Present perfect (Newton's work has fundamentally changed…): describes things that happened in the past but still have consequences in the present.*
- Abbreviations and acronyms are used to prevent space and tedious repetitions and should only be used for terms that are frequently used (say, more than 5 times). Always spell out the abbreviation or acronym the first time it is used, both in the text body and in figure captions. Try to avoid using abbreviations in figure, tables, captions and the title.
- Mathematical variables have to be introduced the first time used and must be unique. Never use the same notation for different variables. All physical quantities need to include their units, in standard SI units.
- "This" and "These" must always be followed by a noun, so that its reference is explicit.
  Not: This led us to conclude...
  But: This observation led us to conclude…
- For numbers larger than 1000 or smaller than 0.001, use a power of 10 unit (10^3 or 10^{-3}).

Final words

Adaptation of the rules and guidelines provided in this document help you to increase the quality of your written scientific documents and streamline the writing and reviewing process, tremendously. Writing is hard work, but with practice you'll become better and better in it! What you see in scientific journals is usually a product of frequent rewriting and revision to make the text as clear and concise as possible. (This text has gone through 3 revision rounds and 4 peers have looked at it, it took me days to prepare and will probably be improved further

in the upcoming months). As such, when you write: go ahead and draft a paragraph using the words that come to you naturally, then revise and rewrite, and revise again with paying attention to your writing style (can you improve your accuracy, precision, clarity and concision of words). Reread your text the next day or let it read a peer and revise again. Look back at your first draft, do you see your improvement? Is your current version as clear as you could do, or could you still improve more?

Additional literature:

- Mack, C.A. How to write a good scientific paper. 2018 (ISBN: 9781510619135), freely available under: https://spie.org/samples/9781510619142.pdf
- Whitesides, G.M. Whitesides' Group: Writing a paper. 2004 *Adv. Mater.* **16** 1375-7
- Good LaTeX template: https://www.overleaf.com/latex/templates/tud-report/qrntwbrqpckw