

# How to Write a Great Research Paper?

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## INTRODUCTION

Writing technical report or research papers is a inevitable task encountered by all scientists and engineers. It often generates stress, trepidation, fear, and lack of interest. However, this is not a fatality.

**The main idea of this article is to propose 15 recommendations you can apply, to turn the painful exercise of technical writing into an enjoyable and productive experience.**

Disclaimers: I am yet neither a prolific writer nor an experienced scientific paper author. But as most of you, I already had to complete quickly massive technical reports, Uni assignments, and others. In my quest for continuous improvement, I wanted to learn from experienced writers, conferences, and books how to be more efficient. On the basis of my findings, here I share with you some recommendations. I encourage any of you to add to this with their own experience and advises below.

In this article the term “research paper” covers not only publication in scientific journals, but also technical reports, student research assignments, thesis, and general technical documentation not necessarily requiring peer-reviews.

Here is a list of the recommendations covered by this article, for which the details are provided in the following sections:

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## 1. Start with the misconceptions.

**You always have to start with the misconceptions:** Indeed, you probably think that you should aim for high quality explanations? This is **NOT** enough. Actually, in some cases, a clear expository summary is **worse** than no explanations at all. You could describe as clearly as possible a physics principle with beautiful animations and schematics to an audience: this is almost pointless. Indeed, the key for effective educational communication is to start (when possible) with the misconceptions: clear explanations are not enough. In his PhD thesis, D. Müller showed that when presenting something to an audience with a very clear media, they come with their preexisting idea of the why the world works that way. The audience think they already know it. Hence, they don't pay that much attention to what is explained and don't realize that what is presented differs from their prior knowledge. Sometimes, they even get more confident in the misconceptions they were thinking of beforehand.

Instead, you should start your document or presentation with a clear statement of the misconceptions and refute the claim with evidences. You may notice your audience to be more confused at the beginning; they may ask questions, read the same page 2 or 3 times; but this is exactly because they are making more mental efforts to actually understand the idea, and supersede their misconceptions.

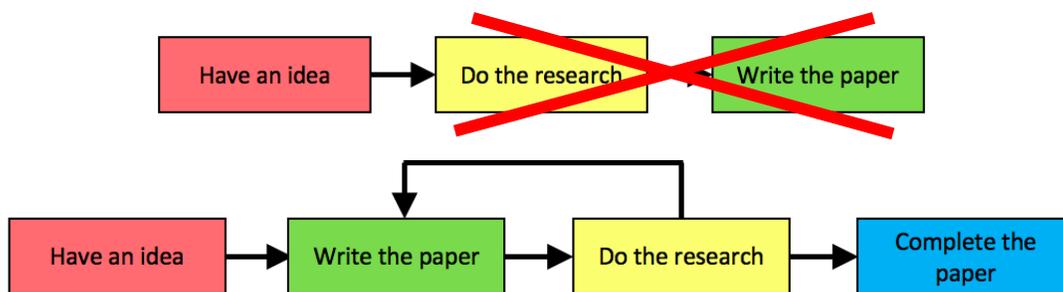
## 2. Don't wait, write!

**Writing shall be the starting point of your research, not the end.**

You probably have learnt that research, engineering and technical investigations should follows the following sequence:

1. Have an idea
2. Do the research
3. Write the paper.

This makes sense, no? It is what we are asked at school after group projects, laboratory classes, or internships: to write a report about our work. This is how me and you learnt it, how you do it, and how you might continue to do so. Did you already end up 1 week only before the conference, or 2 days before the submission deadline of your Uni research project assignment, with all the lab work done, scattered notes, but a blank page for your paper? If yes, you know how trepidation appears, and stress is rising. You just finished the most exciting part of the job, and now you struggle to deliver that paper on time! Bet what? This is a misconception. The process should not be so rigid. It can be done differently, and I will argue that it shall. Writing needs to be started as soon as possible, even before actually starting the research, as shown below:



Now let's elaborate on why we should start to write prior to conducting any research:

If the writing task is so painful it is exactly because it requires mental efforts to leverage your understanding of the topic. The cognitive demand enables to formalise ideas: it forces to be clear, focused, and to structure your disorganized thoughts. The writing phase follows the ideation phase. Don't wait, write. It is obviously far better to start your work with better organised ideas. On top of that, are now using the writing process as a tool to crystallise your understanding of the topic and to guide yourself through the research tasks.

### 3. Put your readers first.

**You have to design your document to meet the need of your readers.** All texts have readers: it can be your professor, a jury, the general public, or even yourself if it is a rough lab report for future work. Readers have needs to pursue their own goals. Your writing shall aim at fulfilling the readers needs and facilitating their work. Your task is to convey a useful, novel, and reusable idea as clearly as possible from your head, into the head of a reader. So keep that in mind: satisfy **their** needs.

### 4. Readers are not detectives!

Whatever you write, try to be as clear and explicit as possible. Write for the most stupid reader, and don't let the reader to be a detective. Don't assume that he will figure out ! Don't assume that he knows what instrument you've used to take this measurement or which equation to use get to this result. However, if you are constrained in size for the article, then provide the details in supplementary material. Another option that I like is to refer to the literature, to relevant handbook chapters which already covered some elements of discussion.

### 5. Is your idea OK?

**Great article contains an idea which is useful, reusable, and novel to some extent.** The idea can be your research question, your finding, your theory, etc. It needs to be very clear for the reader what the idea is (see recommendation 7). A great idea has the 3 important features: useful, reusable, and novelty.

**Utility** because we aim to address a specific need / question / or to add value to the society. A mathematical model might be very useful to predict the response of a system very accurately. However, that does not imply that it is useable, in practice.

**Reusability** is therefore the second criteria. It refers to the readers' capability to reuse and implement the presented idea to resolve their problems. To fulfill their needs and achieve their goals. A clear description of the idea, after elimination of misconceptions (see recommendation 1) shall permit the readers to take advantage of the usefulness of the idea (e.g. to collect necessary data allowing to predict the system response very accurately with the useful model).

**Novelty.** This is the third criterion. In our example, how did we achieve this high prediction accuracy? The novelty can be a new approach (e.g. use of machine learning) or the access to a new set of data prior to anyone else. For efficient communication, you need to catch early in the article the reader's attention. Inform him what the novelty is with respect to the other papers he had / has to read. Novelty doesn't need to be a revolutionary concept. Novelty lies under a different approach during the investigation (material, method, interpretation, metrics), optimization, addresses misconceptions, uses new data, and could bring evidences or may refute a theory for unexplored reasons.

### 6. Define the purpose.

A Purpose-driven walk is by far more efficient than a random race. Prior to writing, ask yourself and write it down:

**The purpose of this document is \_\_\_\_\_.**

This only takes you one sentence and could be of great help. It won't appear in the manuscript. However, with a clear note of the purpose for yourself, it becomes easier to articulate your style, organize the idea and the general workflow. Indeed, whatever you write in the article, ask yourself to which extend it serves the *purpose* of the document.

This approach can be valid for short memos or emails. For massive documents, like a thesis, you would still have one high-level purpose, but additionally, write down the purpose of each individual chapters and how do they support the overall purpose.

## 7. One main idea / question per paper.

How many times have you read a paper, and managed to summarize in one single sentence what the main idea was? If your reader is able to do so, then you've done the job correctly.

After having defined a clear purpose, you can complete the following:

**The key idea of this paper is \_\_\_\_\_.**

It can also be rephrased as:

**The main question behind this work is: " \_\_\_\_\_?"**

This is what you want your readers to remember. Don't forget, your primary objective is to convey a message. You want to transmit your idea from your head, into the head of your reader. The more focused, clear, and explicit you are with your audience, the easier it is for you to get your message into their brain. I would even argue that a statement of the key idea / research question should be written as it is in the real article. Don't let your readers to be detectives (see recommendation 4): tell them in the most direct way. If you write such a sentence: *"The key idea of this article is: blah blah blah"*, their brain will turn it into *"Warning, this is the payload: blah blah blah... Ok, that's what I have to remember... I'll flag it..."*.

To avoid confusion and to not lose your readers: one main idea / question per article in a single sentence per paper could be your motto. And what if you have many ideas? Then write many papers, or a book with several chapters!

## 8. Do you know your readers? An audience analysis checklist.

Audience definition is crucial for rendering technical information usable to readers. It is a misconception that we do all think the same way, and therefore we also don't read the same way. Sensitivity to information is different from one individual to another. There is no right way to do it, but some communications strategies are more efficient. The following checklist will help you to carry this early audience analysis. Also, remember: *"We might not always tell readers what they **want** to hear, but we should always give them what they **need** (and should wanted) to know."*

So before you start to write anything, I advise you to go through the following **audience analysis checklist**:

Who are the readers?

- Who is your audience? (e.g. Undergraduate students, Biology researchers, professional network, etc.)
- What is their educational and professional background?

What do your audience know about the subject?

- What do the audience know about the specific topic of your report or paper?
- How much background is necessary? The answer allows you to start thinking about the introductory section of the paper

What does the audience need to know?

- What information does your audience need from your report or paper to do their job better?
- Shall it be more technical, managerial, public relations, marketing?

What will readers do with the information?

- Will readers perform professional tasks? (a user manual / tutorial format might be appreciated in case)
- Will readers use the information in your report or paper to increase their knowledge of the field? (if yes, link your statements to the literature, book or paper of reference in the field, reviews, etc.)

What personality types will be reading? (shapers, implementers, team coordinators, creatives?)

## 9. Organize the global narrative workflow

A great structure and narrative flow are just like a map. It helps to drive smoothly the reader to your idea, and makes it easy to remember.

To establish the structure of a document, I recommend drawing **mind map to best organize the idea and related elements**. Use this tool to expose relationships between ideas, facts, and supporting facts of what you need to communicate. Finally,

create the narrative flow. It is the path on which you are going to take the reader so that it makes sense.

Scientific journals usually have author guidelines in which the structure is provided. And you should try to stick to it. Also, you can browse similar papers that were published in the journal of interest and identify the recurring successful pattern.

Alternatively, here is a global narrative flow that you could apply in most technical papers:

- **Introduction / Lead**
- **What is the problem?**
- **What is the idea?**
- **What are the details / evidences / results?**
- **Related work**
- **Conclusion / Exit**

This is a problem-solution-benefit structure, which is desperately simple but powerful. You might notice that the related work section is not at the beginning of the document but is the last section before the conclusion. This is done on purpose to not lose the reader. This is further discussed in recommendation 14.

When organizing the narrative flow of your paper, build an outline such as the one proposed. Based on the mind map, create subsections. Populate each section with keywords or brief statement of what you intend to mention in each of them.

## **10. Rapid drafting**

The next logical step is to write a **rough draft** of the body text. Here are a couple of considerations:

- Resist the temptation to correct mistakes. Do not edit your text as you write the draft. Your job is here to write a rough complete first draft. Editing is the next critical stage. But editing while you write the draft is a waste of time. It is extremely difficult to not stop and correct yourself as you write, but always remember: **Fixing a sentence to make it perfect if it does not appear in the final paper because it turns out to be irrelevant is a waste of time.**
- Do not write the full introduction now, only your contributions. Start with the body text (problem, idea; details; related work).

Based on the narrative flow (recommendation 9), proceed as follow: break down each section and subsection into paragraphs. To do so, write the first sentence (lead) of each expected paragraph in the body text. Each paragraph shall contain one bit of information, one supporting fact, one discussion, one “micro-idea”. That information shall be captured by the leading sentence of the paragraph, and ideally a lazy reader would have a good understanding of your paper by reading only the first sentence of each paragraph.

Here are some other important considerations:

- As much as possible, ask yourself “*Does it support the main idea of this paper and only this main idea?*” if the answer is no, you should really consider deleting it.
- **Do not drive your readers to dead-ends!** After having read the introduction and the contribution claims, the reader should not be surprised anymore by what he reads in the paper. If you are willing to mention an experiment who did not achieve the performances you were looking for, it is perfectly fine to include it to your paper. And surely this will help others researchers who intend to reproduce it. However, you are not writing a novel with an intrigue. So make it explicit as soon as you start to discuss it. Here is an example:
  - **Bad:** Genetic algorithm is employed to do B, C, and D. Blah blah... [2 pages]... We can see that the model error is not compliant with the requirement.
  - **Good:** When employing genetic algorithm to do B, C, and D, the resulting model error is not compliant with the requirement. This is how we carried out our investigations: ...[blah blah... 2 pages].

## 11. A good introduction

This is, after the abstract, the most important part of the paper because it is usually after reading of the introduction that the reader decides whether or not it is relevant to read the rest of the paper.

- Give the context: you can start by giving an example of the problem.
- Give the motivation: What is the need? Why it is interesting to solve / still unsolved?
- Give your contribution with bullet points and reference to the relevant sections of the paper. In the eyes of a reader, the contributions are the specification, and the references enable him to quickly go to the evidences. Each contribution claim shall be a refutable statement.
  - **Bad contribution claims:**
    - “We describe the ABC system”
    - “We study its properties and performances, it is much better than other systems”
  - **Good contribution claim:**
    - “We give a functional tree of the ABC system including a mass and power budget of the subsystem X (section 3).
    - “We compare its field of view and pointing accuracy with US and Russian state-of-the-art systems (section 4).”

## 12. No mountain: mound!

Do not pretend that your paper is going to solve a mountain-like problem. Instead, be specific and describe the mound conquered by your work.

A great approach is to explain the problem as you would have done it with your audience in front of a blackboard:

- Start with a specific example of the problem;
- Generalize (if applicable);
- Recall why it is an interesting problem to solve (scope beyond, others...) and why it is unsolved (if possible).

This section is where you could introduce the bit of required background information. But do not overload the reader with 5 pages of literature review! This would be the best way to lose the readers and to not get YOUR message conveyed into their brain.

## 13. Describing the idea, the details and the results

Give the big picture of the idea being investigated, and double check that you covered utility, reusability, and novelty (see recommendation 5).

Here you show how it works. It is the meat of your paper and typically includes two sections that are the largest of the paper. There are also the easiest to write because it the core of your work.

- Materials, Methods, setup, simulations, etc. (be very specific);
- Results and discussion. It’s the right section to point out the weaknesses (e.g. uncertainties, limitations, etc.) of your work instead of hiding them until a nasty reviewer or reader discover it).

## 14. Related work and literature survey: at the end of the article!

Once you’ve conveyed your message / idea to your reader’s mind, it is the right time to compare it to the related work and the literature. However, to make your work looking good, you don’t need to make others’ work looking bad. You can list the differences, where you are better, and worst. Therefore, try to be objective and do not hesitate to give credits to the great papers that were inspiring for your work. It also adds value for additional reading if your audience is interested.

This section could also be merged as part of a “Results and discussion” section.

## 15. Editing checklist and polish

When the complete first draft is ready, utilize the following editing checklist:

- Abstract: does it convince your target audience to read the full paper?
- Introduction:
  - Does the sequence context / motivation / idea / contribution works?
  - Is there a 1-sentence idea / research question statement?
  - Are the idea utility, reusability and novelty introduced to let the reader know how to better perform its job?
  - Do your contributions claims are refutable and presented with a forward reference to the relevant section of the paper?
- Body text + Exit
  - Is it compliant with what is announced in the introduction? Are the evidences wrt to the contribution claims provided ?
  - Are the ideas well organized and does it make sense?
  - Are there transitions and is it interesting?
  - Does it support the main idea and only the main idea?
- General checks:
  - Have you followed the journal guidelines?
  - Is the style appropriate for the topic and audience?
  - Are there typos? Is the English and the punctuation OK?
- **Technical Editing:** ask a colleague or an expert in the topic to make sure there are no technical / scientific mistakes.
- **User Editing:** ask some person representing your target audience to give you feedbacks.
  - When are they lost in the paper? When does their brain disconnect?
  - When is it boring?
  - Do the ideas make sense to them?
  - Can they briefly summarize what was the paper about?

## CONCLUSION

We all face the task of technical writing, and that is often not easy. The main idea of this article was to share some recommendations that I implement to improve my own technical writing activities into an enjoyable and productive experience. Feedbacks would be gratefully appreciated and now, I am curious to know what are YOUR tips and tricks?

Sources and supplementary materials:

Derek Muller PhD – The key to effective educational video

<https://www.youtube.com/watch?v=RQaW2bFieo8>

Book: how to write good technical information charles H. Sides:

<https://www.amazon.com/How-Write-Present-Technical-Information/dp/1573561339>

Simon Peyte Jones – Microsoft Research Cambridge

<https://www.youtube.com/watch?v=VK51E3gHENc>

Prof. Pete Carr (faculty member at the University of Minnesota, Department of Chemistry):

<https://www.youtube.com/watch?v=UY7sVKJPTMA&frags=pl%2Cwn>