

What Paper Are You Working On?

Advice on how to do research

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True confessions of a former neophyte

I was a student a long time ago. I had a fairly traditional education in writing. First I learned how to spell. Then I learned a little grammar. Then I learned the basic structure of the paragraph—topic sentence, a few sentences of development, and a closing sentence. In high school I had to write longer documents that the teachers called “papers.” Some of the teachers called them “research papers.” As far as I could tell, research meant gathering a few books on a given (usually assigned) topic, extracting nuggets of information (and writing those down on 3x5 index cards), and sorting the nuggets into an orderly form. Once the information nuggets were properly sorted, you proceeded to write the paper.

Back then we had a device called the typewriter to prepare written documents. The typewriter was a great invention (arguably the greatest advance in communication since the printing press), but it was a device that was not very well suited to the task of making modifications to what you wrote. More often than not, if you wanted to do something as simple as move a sentence or change the order of words in a sentence, then you had to start over typing on a blank sheet of paper. It was not possible to do equations (unless they were extremely simple), but that was not a real issue back then because research topics never involved mathematics. Figures had to be drawn by hand. Putting ideas down on paper, in any sort of formal sense, was very hard to do—way too hard to do.

Perhaps it was a result of having primitive tools. Perhaps it was simply in my nature. For some reason, I developed a style of writing wherein I felt compelled to deliver the words in final form to the document (or not at all). I found it very hard to think in complete paragraphs. But if I couldn't, then the page remained blank. The struggle of completing ideas in my mind before committing them to paper was a terrible burden. So awesome was the task of writing that I learned to loathe it.

To make a long story short, I was trained not to write. All indicators suggested that avoiding writing was a good idea. Writing was painful; revising was next to impossible. The real indictment, though, was that writing research papers was absolutely pointless. I never could figure out why I had to write a paper on Japanese drama for Mrs. Stephenson's class.

Then I got a job for which writing was, for all intents and purposes, a job requirement. Time had passed, tools had gotten better, and I had learned some things (specifically, structural engineering) that really piqued my interests. With the improved environment and a lot of strong professional encouragement, I managed to “discover” writing. What I discovered really surprised me. It wasn’t the obvious discovery that if you practice you will get better at it. It wasn’t a discovery about good spelling, grammar, and word choice. I didn’t discover outlines, paragraphing, and other organizational techniques. I already knew a lot about those things.

I discovered that writing is thinking.

As a corollary of my discovery I soon realized that the primary result of my loathing (and subsequent avoidance) of writing was a serious restriction on the flow of ideas coming from my brain. I had found my way to a career in scholarly research. But my range and evolution as a scholar had been distinctly limited by my inability (or lack of inclination) to get my thoughts on paper.

Research and scholarly writing

The goal of research is the discovery of new knowledge—solving problems that no one has solved before. Scholarly publication is the act of presenting the results of your research to the community, in writing, so that all can benefit from the new knowledge generated. There are some differences in the nature of research across the various academic disciplines. Even within the context of engineering research the goals and drivers of research are not all the same. However, there is one thing that is common to research in all fields: The primary tangible outcome of research is a scholarly article—a research paper. Research papers are the currency of the academic community. In the academy we take publication of ideas so seriously that we have developed venues (archival journals) and quality controls (the peer review system) to support the endeavor.

A large part of research is learning. The researcher actually spends quite a lot of time going over well-trod ground. One cannot advance the knowledge of a field if one does not know the basics of the field. Newton said, “If I have seen farther than others it is because I stood on the shoulders of giants.” You have to solve the already solved problems (at least some of them, perhaps all) to get enough traction to make a new contribution. It would seem, then, that learning (and therefore research) is more about reading than it is about writing. The things you do during the learning phase of research are not usually publishable. Most of the time these ideas have already been published and your task is simply to catch up with what is already known.

So, writing is something you do at the end of research then, right? You do the research, you get the results, and then you write it up, right? You gather some books, take some notes, rearrange your notes and write the paper, right? Wrong.

Writing is more than the communication of ideas. It is more than documentation. Writing is thinking. And you really should do the thinking as part of the process of research all along the way. The new knowledge will be better for it.

Why write now?

Most neophyte researchers labor under the erroneous assumption that the only appropriate time to write is when you have a research result that you think is worthy of publication—a new idea, already developed, ready to write up. This assumption is erroneous because it shortchanges writing as an essential tool for *working out* research ideas. The act of writing disciplines you to remain sensible about your research. Writing shines a light on your work that can help you ferret out lack of relevance, false motivation, theoretical hand waving, and other research poisons.

Every technical article has certain required elements: An introduction, a section that describes the theory or the experiment, a section that describes the results or the application, and a conclusion. Writing each of the sections helps the research in different ways:

(1) *Writing the introduction*

Writing the introduction forces you to put your research into a context. Is there a purpose to the research? Is the research relevant? Is there a history leading up to your contribution? Can your research problem be succinctly stated?

If there is no purpose, relevance, or history then the introduction will be almost impossible to write. If there is purpose, relevance, and history then the introduction will practically write itself. The purpose of the research may evolve as the research progresses; you may think of new ways in which the research is relevant; you may uncover new references that tell you about the history. You may need to rewrite the introduction several times to account for your revelations, but the truth is that the act of writing the introduction will be one of the key forces driving those revelations.

The introduction is where you try to talk about the research at a level accessible to a more general audience. You should be able to describe your research problem in simple terms—terms understandable at least to all reasonably educated people in your field. I maintain the goal of passing the “Grandmother Test” (my grandmother did not have a Ph.D. in structural engineering). If your grandmother were to read the introduction to your paper and thereby get the general idea of what the paper is about, then the introduction passes the Grandmother Test.

Write the introduction early and often. And do send a copy over to grandma.

(2) *Writing up the theory*

Writing out (indeed, typesetting) mathematical derivations may seem tedious, but it is absolutely necessary. First, you must find your own voice and notation for the derivations if the paper is on theory. If you don't then you will never completely own the ideas and you will be held back from making advances. Don't buy into someone else's way of expressing the theory (for one thing, it might be wrong).

Second, if you are writing out the details of a derivation, then it gets to be much harder to fool yourself. At the very least, you can see where are the great leaps of faith. You can clearly see the hands waving when you feel inclined to say, “and after a miraculous sequence of fortuitous mathematical coincidences, the following equation emerges from nowhere...”. The writing keeps you grounded in first principles. The writing keeps you honest.

(3) Writing up results

Writing about the results of your research forces you to think productively about what you want to present and how you want to present it. Going through this process can protect you from perishing data. If you are generating your information from a long and laborious computation, you might save yourself from redoing all of those calculations long after you have forgotten how to do them effectively. More than once I have gotten a draft of a paper or thesis from a student and quickly recognized which parameters *should have been varied* and which example problems *should have been solved*. Sometimes it is not feasible to redo an experiment or a computation. Writing around what should have been done is very, very hard to do. Let the writing uncover these unpleasant things early.

(4) Writing the conclusion

I am not such a stickler for writing the conclusion early. You can leave that for the end so that you can capture a sense of awe and wonderment when you really see how the paper turns out. But be warned. If you don't have any conclusions when the time comes then you don't have a paper.

And the best reason of all for writing now is...

The therapeutic effects of writing as means of doing research are certainly worth the trouble. But there is another merit that makes it quite essential in a collaborative environment: Writing gives you a medium of exchange of ideas with your collaborators (e.g., your research advisor). It is very difficult to track the progress from casual periodic discussions—even those discussions that benefit from the white board or the yellow pad. The devil is in the details, and so are the answers to most of the vexing research questions. An effective exchange with your collaborator might be able to save you enormous amounts of time.

Writing is a good research habit

A good, productive researcher should always have a ready answer to the question “what paper(s) are you currently working on?” I expect each of my students to accept, among the duties of a researcher, the following practices:

- Know the title of the paper you are currently working on (even though it can, and probably will, change many times) and write the introduction (and revise it when it seems appropriate).
- Typeset all important derivations and glue them together with enough words so that someone other than you can read and make sense of them. Work hard to find the right notation for equations. Learn how to write mathematics. This action, by the way, implies a good choice of word processor. I encourage the use of *QuickSilver* because I use it. I am also agreeable to *LaTeX*. Don't use anything that makes the typesetting of mathematics difficult or ugly.
- Plot important results as you get them. Get in the habit of preparing publication quality charts. Worry about line quality, significant digits in the axis labels, readable fonts, and completeness of descriptions. Don't waste your time preparing a chart or figure that you will not be able to understand or explain a

month later because you didn't take the time to be complete and accurate. (I recommend using *Logos* or *xfig* for producing x-y plots).

- Maintain a short list of journals for which the article might be appropriate. Each journal has a certain style for things like references and often you can save time later by getting the right form early. You can also use articles in your favorite journals to help you to establish an acceptable style.
- Agitate about getting written comments on your work. If you want feedback (and you do) then you should ask for it. I have an endless supply of red pens and I am always more than happy to use them. But I am very busy; it is your responsibility to assure that your stuff does not get stuck on my back burner.

Don't expect your progress in writing to be uniform. Recognize the important cues and use them to your advantage. If you get stuck in your writing, the paper may be begging you to search for something in the literature or write a computer program or do some act of research. Do the research. Feel free to speculate and frame hypotheses. But, don't write fiction.

Writing still isn't easy

Unfortunately, recognizing the importance of writing does not make the act of writing any easier. Writing is a struggle, and for most people it always will be. My friend Juan Simo was the best researcher and writer I have ever known. He once told me that every paper he ever wrote seemed like a titanic battle. He was very brave and he won lots of those battles. There is a real sense of accomplishment that goes along with emerging victorious. It keeps you coming back for more.

Publishing is research perfection. Be warned that the fear of the perfection can keep you from writing anything. View your papers as *working papers*. With perseverance (and a little luck) your working papers will eventually turn into published articles. With experience and practice the fraction of your working papers that turn out to be publishable will increase—maybe to 100%. If you set out to write a masterpiece then you never will. If you set out to write with the intent of clarifying your ideas, then you will publish many excellent papers.

The thesis

For most new researchers there is a test of accomplishment called “the thesis.” The thesis is the document you write to earn your degree.

There are different schools of thought on the best way to work on a thesis. I think it is most productive and efficient to think of your thesis as a collection of journal articles bound together with an introduction and conclusion rather than it is to think about carving papers out of your thesis after it is done. There is much pain associated with carving and once the thesis is deposited your motivation can take a precipitous drop. Although not all topics are amenable to this one-article-per-chapter approach, most are and it is good to do it if you can.

When you go to defend your thesis in front of a faculty committee, and most of the contents of that thesis have already been subjected to the peer review of an archival journal, you will benefit from the security that your ideas have already been tested.

Closure

There is no formal way to teach someone how to do research. It still tends to be education by immersion. Perhaps the closest we ever come to “teaching research” is to teach writing. Make no excuses. Statements like “I don’t like to write” or “I don’t write well” are, to the researcher, roughly the same as “I don’t like to think” or “I don’t think well.” There is no place for such an attitude in the research environment. A scholar would certainly not be inclined to make those statements about thinking. Why should we approach writing any differently.

I think it is safe to say that you have not really done research until you have written (and published) your first paper. You may have pretended to do research. You may have emulated a researcher. You may have talked about doing research. You may have held the title of Research Assistant. But writing that first paper is a certain rite of passage.

I think it is also safe to say that you cannot justifiably call yourself a researcher until you have embraced writing as an essential element of research. Simple proof of your claim to be a researcher will be a steady flow of your ideas into the archival literature. Publishing papers in the archival literature is a sufficient, but not necessary, condition to qualify you for the Ph.D. degree (in my opinion).

What paper are you working on?