

Matter of Opinion

10 tips on how we write papers

Edward H. Sargent^{1,2,3,*}

Continuing *Matter's* series on authoritative tips for manuscript preparation, Edward Sargent shares ten tips on writing successful research articles.

As a mentor to doctoral students and post-doctoral fellows, I put a particular investment of my own energies into the *input* and *output* phases of the research process. The effort involved in between—the background research, experimentation, data analysis, etc. that define the investigation—is typically in the hands of the students and fellows.

The input encompasses setting a research project goal, often consisting of an applied target accompanied by a key scientific question that needs to be addressed to inform a new design to meet said applied target. At this initial stage in the process, I offer my own reflections on the student's project vision and strategy/plan, but, at least as importantly, I seek to bring together a small team to critique, iteratively, the student's target, hypothesis, and plan of approach.

The output involves communicating the results to others—i.e., creating the manuscript for submission to the journal. This article is about our process regarding the output.

Seven tips on crafting papers

- (1) **The art of positive visualization: start with the figure set.** I learned early in my career from eminent colleagues that one good strategy can be to start with the figure set... even before we have the full and final set of data for the paper! It's a great aid for crafting the logic and flow of the paper. The holes in this emerging figure set are the

still-remaining work items on the critical path to the paper. This helps the first author prioritize the remaining time spent.

- (2) **Outline the logical flow and narrative: get lots of feedback at this stage. This is the time to iterate and optimize the logical flow.** Before writing prose, write—as bullets or a flowchart—the logical sequence of ideas, and transitions therebetween, that will make the work most clear. Discuss *this* a lot with colleagues and advisors. When you get this right, the manuscript will (almost!) write itself. This is the time to iterate, shuffle the deck, reorder, or realize there's one key experiment missing. If you get lots of feedback at this stage, there will be fewer tears later—such as when you present a “perfect” manuscript to your advisor that you've polished so much that you can't bear to see changes/edits.
- (3) **The best narratives are almost never chronological accounts of your actual real-time journey through the project.** You did the work in some order: you had an idea, you tried it, it failed, you had another idea, you thought that worked but later discovered it was an artifact, you went to play Spikeball, etc. Not only do you not need to tell the story in the order in which it happened... but it will be hard to follow if you do. See item 2 above: work with the outline; iterate on the outline;

and develop a sequence that flows, is easy to follow, and engages the reader.

- (4) **Failed early attempts can help you create a dramatic tension and a feeling of anticipation in the reader.** Sometimes I see drafts in which, early in the abstract and also early in the manuscript, we jump too soon to: “Here we find that, by using 2-N,4-N,6-N,8-N-snuffleupagus(3-methylphenyl)pyrimido[5,4-d]pyrimidine-2,4,6,8-tetramine as hole transport layer, we achieved a record solar PCE.” If the first thing that we tried had worked, the accomplishment is less likely to have been a substantive advance informed by deep and original reasoning. If you look back at how the work actually went in the lab, often your first attempts—the preludes to your eventual and ultimate success—did not proceed as hoped. You tried the obvious things that a reasonable expert would have done... and the approach failed. This sets the stage for your eventual accomplishment and will highlight that it was not trivial at all: instead, it required innovation. We then seek to learn from these failures—study their origins. What is it, mechanistically, that accounts for the fact that known prior art, when straightforwardly combined, failed to produce the intended result? These studies may well spotlight a factor that has been previously

¹Department of Electrical and Computer Engineering, University of Toronto, Toronto, ON, Canada

²Department of Chemistry, Northwestern University, Evanston, IL, USA

³Department of Electrical and Computer Engineering, Northwestern University, Evanston, IL, USA

*Correspondence: ted.sargent@utoronto.ca
<https://doi.org/10.1016/j.matt.2022.09.025>



overlooked or underemphasized. The new model you develop will inform how you'll innovate your way out of the problem: only by doing X were we able to overcome this now-understood mechanism that we now know was at the root of the failure of the obvious combination.

The approach I outline above isn't the only way to write an interesting and engaging paper. It illustrates a broader principle that does cut across many good papers: they have a plot. Often there are struggles and disappointments; then a suite of studies motivated by curiosity, driven forth by the instinct to investigate; then a phase of innovation enabled by the resultant insights; finishing with a significant achievement that relied on the innovative step.

- (5) **Stand proudly on the shoulders of giants and delineate clearly when this tribute is complete and where we have moved on to your original work.** The literature review should be generous to those who have come before you and whose works form the foundations of what you're doing. Once you've done this, transition clearly, with a fresh new paragraph, to your new effort/hypothesis/attempt. Consider using different verb tenses or other markers to delineate clearly {the tops of the giants' shoulders} from {the bottoms of your sneakers}.
- (6) **The harm, and the cure, should be commensurable—in proportion with one another—and should be precisely formulated.** To borrow from the brilliant Prof. Yogi Surendranath: if the harm (problem to overcome) that you present is "the world emits 39 Gton CO₂/year," then the cure (your achievement) needs to be that you reached carbon neutrality by the end of the paper. If the

harm is "the mechanisms of degradation of perovskite solar cells are incompletely understood..." then they'd better be completely understood by the end of the paper! The harm and cure need to be suitably modest, precise, and in proportion with one another: "In sum, 2D/3D perovskite heterostructures provide major performance advances, but have so far failed to translate to inverted cells; here we report a method that tunes the band structure of 2D perovskites to address this problem, enabling as a result electrons to travel upward to the electron-collector without barrier."

- (7) **Use an economy of words, and submit the paper when it is 90% perfect.** Referees will always ask you for more work, but it's hard to predict exactly what they'll want (which is the beauty of the peer review process: there is huge information content and value in what we learn from reviewer feedback, evidenced by the fact that we cannot predict what it will be). Reviewers will always find something, and it will always help make the paper better, and by leaving a bit of room to fill out the paper in light of their feedback, you've created an opening for reviewers to offer worthwhile feedback that you can act upon.
The hero of my hometown, Sir Terry Matthews, was reputed to say: "When you're a start-up, the purpose of making a product is to get the chance to show it to a customer—so that the customer can tell you which product you should actually make!" When you submit an article to a journal, you engage with expert referees and secure their feedback. With the aid of their insight, you learn what is required for you to take this paper the rest of the way to publish-ability.

A few warts might be okay; the paper must be of sufficient quality and rigor to engage the referees in a substantive expert conversation. Even if you think it's perfect, the referees won't!

Three additional considerations

- (8) **Interpret peer review comments through this lens: how could I use this feedback to improve the work?** Referee reports often contain constructive recommendations that are clearly intended to help you make the better paper. Sometimes they also contain language that you'll experience as harsh or negative.
And yet, it's always possible to find the constructive in what feel like criticisms. Ask: "if what I wrote originally left this impression with the reviewer, then how could I revisit my studies, their interpretation, and their presentation to create a more balanced perspective?" Often harsh feedback contains clues to a misunderstanding—and thus a chance to improve clarity in your next submission. Often the feedback is an invitation to acknowledge alternative interpretations of your findings—ideas that weren't part of your original agenda, but that, once captured in the revised manuscript, communicate your openness of mind and thus invite a future conversation in the literature. I try to avoid arguing with referees in my point-by-point response; instead, I try to show how we've made the work better in light of the broader spirit of their feedback.
- (9) **On cover letters.** In my experience, journal editors read the cover letter *and* they read the manuscript. For this and other reasons, we don't retread the same territory in the two documents. Typically, the cover letter will be a bit more engaging, a

bit more accessible, and a little more zoomed out. It will contain one visual element—a graphic or a table—illustrating the main new idea and the applied achievement, i.e., the new quantitative figure of merit achieved relative to relevant prior art.

I tend to offer about 10–12 referee suggestions. This sounds like a lot, but editors at even the highest impact factor journals have a surprisingly hard time finding referees. I take a *Team of Rivals* approach to suggested referees: I recommend the people in my field and in nearby fields who are the most rigorous, the most expert, and thus those who are also my direct competition. In this way I get the highest quality feedback, and I communicate to the editor my confidence in the work. I don't ask for re-

viewers to be excluded.

I aim for diversity in the list: intellectual diversity, of course (some who could review the theory, others who could review certain key experimental methods, and some who appreciate the systems-level big picture), and, crucially, also diversity of geography, gender, career stage, and beyond. Diversity, equity, and inclusion permeates every stage of the research and graduate training process today, as it should, and so it should too for peer review.

- (10) **Do as I say, not as I do.** A reader will detect some of the above elements in our group's papers from the past 24 years, and many violations of these guidelines as well! What I wrote above is a summary snapshot of how I think, at breakfast on a day in

July 2022, about the art and science of paper writing. It has evolved in time, and it continues to be dynamic to this day. I encourage all to develop and evolve your own philosophy of scholarly dissemination, to pause periodically to write this down as an intentional approach, and to bring your own personal lens to how you communicate about your work. I hope that this letter will spark for me some follow-up conversations with students, post-docs, and faculty members as we continue to update our vision of the process of journal article writing, and I welcome that dialogue.

DECLARATION OF INTERESTS

The author declares no competing interests.