# COMPOSING SCIENCE

## A Facilitator's Guide to Writing in the Science Classroom

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English classes. Other classes draw on those skills but, in general, do not explicitly provide instruction in writing. Similarly, on some university campuses, incoming students often take some variation of a composition course that prepares them to write at a university level. Like the F–12 English teacher, who prepares students for writing in other domains, university instructors, it is imagined, will introduce first-years to resources they will be expected to use throughout their university career: the university library, search engines and style guides; they will work with students on common practices in academic writing: how to embed quotations, include citations, create an abstract and draw from the literature without plagiarising; they will help students in crafting and supporting claims, shaping these ideas into sentences, paragraphs and a well-sequenced paper devoid of grammatical errors. Armed with these resources and skills, students will progress into their majors, prepared to craft papers that argue persuasively for their ideas, to use established conventions and to draw on the literature of their chosen fields and on their own findings. The professors within each major, in this scenario, help students develop the content knowledge that allows them to populate their writing with ideas from the discipline. In this model, science faculty, in partnership with English faculty colleagues, prepare students who understand science and can write skillfully about those ideas.

There are several assumptions underlying this approach to writing instruction – assumptions that research in composition instruction has called into question. Among these are (1) that academic writing is a skill that can be taught and mastered independently of any particular discipline's knowledge and practices; (2) that the "research report" or "five-paragraph essay" written for a composition course is characteristic of academic writing, so that mastering this genre will acquaint students with how knowledge is produced and prepare them for engaging with and producing this knowledge; and (3) that academic writing itself, whether it is the five-paragraph essay employed in secondary education or journal articles and book chapters characteristic of professors' work, is an important focus of our instruction.

This first assumption is widespread: We often describe students as good writers (as opposed to the more specific – and accurate – descriptions: a good poet, a careful note-taker, a persuasive editorialist, a brilliant comic strip author, an elegant proof constructor); we develop tests for F–12 students to assess writing abilities; we sort students into courses and programs based on that ability. And while there certainly are bits of knowledge that transfer from one context to another (e.g. spelling, some grammatical constructions) and strategies that, when learned in one area, may be helpful for another (e.g. analysing good writing to improve your own, engaging in peer feedback and review), it is also true that much of what makes someone a "good writer" is not universal (Adler-Kassner & Wardle, 2015; Petraglia, 1995; Russell, 1991). Writing is an activity that is used by communities for a variety of purposes: What counts as "good writing" in one community may not represent good writing in another.

As one example, one of the authors – Kim, a faculty member in an English department – was asked to contribute a paper and present a poster at a physics education conference; these would introduce ideas from composition to physics professors. When she was crafting her paper, a range of "writing" problems surfaced. She consulted the style guide for how to embed lengthy quotes, but there was no information on how to do this, nor could she find examples in published works. The contrast to her own field, in which extended arguments are presented and built on or challenged as an expected practice (and often constitute the bulk of a claim), was striking. When told she would present a poster, Kim, unaware of conventions and software that are commonplace for presenting work in science, asked, "Do I need to buy a trifold poster board?" Similarly foreign were ways of using data, conventions around citations (e.g. referring to authors by last name only) and the relatively short (four-) page limit. And, of course, without a background in physics education, she had difficulty constructing a narrative for the paper: What kinds of arguments exist in the field? How should she position the work from her field to speak to a physics audience? Academic papers (indeed, all texts) stand in conversation with others, and a large part of learning to "write scientifically" is not only the skillful use of the conventions of scientific writing, but understanding the ongoing conversation and how to enter that conversation. So Kim – a fully competent writer in her own field (composition, no less) – would not be characterised as a competent writer by a faculty member in science. Indeed, the reviews of her paper primarily critiqued the presentation of the ideas, rather than the ideas themselves.

Of course, there are characteristics of academic writing shared among the disciplines. Loosely speaking, what unites the work of university faculty is the production of knowledge, based in methods characteristic of their disciplines, and the sharing of that knowledge, usually through peer-reviewed journal articles or books. While Kim was not familiar with the particulars of how to write for a physics conference, she understood that her paper should fit within a particular style and conversation, that it should build on prior work and that it should make claims and support those claims. And so it seems reasonable that a first-year university composition course might engage students in writing research papers so that they might better understand the ways in which knowledge is produced and shared. Students might then be prepared to do that work within their major – albeit using different conventions. However, this would require that the introductory composition course afford students an opportunity to engage in research. With some exceptions, most first-year composition courses are not structured as research courses, and so students' assignments become, at best, a literature review, an opinion piece or an overview of rhetorical modes, rather than representing any novel research on the students' part. In this way, the work of first-year composition only very weakly approximates the kinds of writing characteristic of academics' work. And so the second assumption behind traditional "composition" courses – that the writing from these courses is, in some way, representative of academic writing in general – is rarely the case (Russell, 1995). And even when it is the case, faculty in science are still responsible for teaching writing particular to the sciences, and they cannot expect that students will know conventions around writing in scientific disciplines.

Finally, if we suspend scepticism regarding the first two assumptions and imagine that there are some commonalities in academic writing that can be taught in composition courses, and that courses are structured in a way to allow that, a broader question remains: Does replication of academic writing – that is, assignments that ask students to replicate the conventions of writing that academic professionals do – best address students' needs? Most students, particularly non-science majors, will have few occasions to read or write scientific research articles, and an awareness of their conventions will be of little use; but all students will be consumers of this research, and we hope that they will be able to understand how the ideas in those articles were constructed, debated and vetted. Our courses should give them an opportunity to engage in and understand that process and the role of writing in it.

Recent changes to curriculum in both F–12 and university settings have recognised this. In university settings, "writing across the curriculum" movements, now widespread, call on faculty in all disciplines to engage students in writing characteristic of their particular discipline. In F–12, the curriculums for English, humanities and social science, science and technologies are calling for more attention to reading and writing in academic disciplines outside of English, and science courses call for teachers to attend to the role of scientific practices – like reading and writing – in developing scientific ideas.

Below we discuss in more depth what we mean by "science writing" (which we construe broadly) and describe the structure of this book and how to use it.

## WHAT SCIENTISTS WRITE

So how do scientists use writing? We scribble on chalkboards, draw diagrams, annotate graphs and photos, jot down ideas in notebooks, send emails, scrawl notes in the margins of journal articles, write grant proposals, review proposals and papers, draft conference proceedings, put together presentations and, ultimately, tidy up all of this work into a publishable journal article. This all takes place as part of the gradual, iterative process of developing scientific ideas in a research community. In science – as in all fields – writing is not just a way to communicate what was learned, it is an essential tool for developing and vetting new ideas. Sociologists of science have gone so far as to propose that writing is not simply a supporting activity – a tool for producing scientific ideas – but can be considered the central activity of scientists. A non-scientist foreign observer in a research lab "soon recognises that all the scientists and technicians in the lab write in some fashion, and that few activities in the lab are not connected to some sort of transcription or inscription". This observer finds the laboratory to consist of a "strange tribe" of "compulsive and manic writers . . . who spend the greatest part of their day coding, marking, altering, correcting, reading and writing" (Latour & Woolgar, 1979, pp. 48–49). In this sense, writing in science courses should not simply present a means of assessing students' writing abilities and content knowledge, but should be a central feature in developing scientific practices and knowledge.

It's often novel, but not too difficult, for science faculty to consider these various and informal forms of writing as what is meant by "writing in science" and to include these as the kind of writing instruction they teach and assess in their courses. What has been harder for us as we have considered our students' writing is to construe writing even more broadly, so that "writing" encompasses not just written words (wherever they may appear), but the simulations, models, diagrams, equations and presentations that are composed alongside – or in place of – those words.

Researchers, however, have long noted that the "role" of text is assumed not only by written words, but also by a host of discipline-specific forms: models, diagrams, equations and so on. A focus on text alone misses many of the ways in which we construct and share ideas, particularly within scientific disciplines. And so in our "writing-intensive" science courses, we should consider not only students' written texts, but also, more broadly, the diagrams, presentations, simulations and physical models they compose as they engage in scientific inquiry. The field of composition and literacy studies now includes these kinds of compositions in what it considers "writing", and when "writing across the curriculum" scholars call on faculty to teach writing in all disciplines, it is precisely these multimodal compositions that they are hoping faculty will include in their courses (Shipka, 2011).

## STUDENTS' SCIENTIFIC WRITING

F–12 students and undergraduates, however, rarely are introduced to these varied writing practices, at least not formally. Instead, literature reviews (a.k.a. "research papers"), school-based lab reports and assignments modelled on the professional journal article are often the only forms of what it means to write scientifically; they are what typically "count" for writing in F–12 and undergraduate science. Style guides, from either journals or course-specific rubrics, determine how students will communicate scientific ideas. While the journal article is a core genre for academic and professional tentative ideas may be revised and refined to argue a claim. Students often have "aha" moments during exams, when ideas come together or a model is extended to a new phenomenon.

Finally, in Part III, "Adaptations: Bringing Writing Strategies into Different Settings", we examine how to use these ideas in other settings. The course where we teach writing in science is an open-inquiry, lab-based course in the sciences, taken primarily by non-majors who are planning on teaching careers. As noted above, a central practice in our teaching is that students are the authors of their own ideas and these ideas are developed in a social context. This is obvious throughout our work, including the kinds of writing that we assign and the way that we assess that writing. We imagine that the ideas in this book will be most easily implemented in courses like our own: small lab courses that allow for extended interactions among students, freedom to explore scientific questions through open-ended investigations, and the foregrounding of students' ideas. We anticipate that many university faculty have some freedom in designing non-majors' courses and can imagine ways to use similar structures in their courses. However, for developers of courses (often those for science majors) that must meet a long list of content goals, large-enrolment courses that allow for limited in-class interactions with faculty and courses without labs, implementing these ideas will take some adapting. We offer a chapter of suggestions for those course designers.

## THE STRUCTURE OF THE CHAPTERS

The chapters in Parts I and II have a standard format. They each address a particular aspect of scientific writing: lab notebooks (Chapter 1), informal but public discussions at whiteboards (Chapter 2), diagrams (Chapter 3), conducting peer reviews (Chapter 4), reading journal articles (Chapter 5), working out ideas on one's own (homework) (Chapter 6), constructing definitions (Chapter 7) and writing a final manuscript (Chapter 8). For each topic, we begin with an introduction to that aspect of writing in science and discuss the role that it plays in developing scientific ideas. In some cases, we provide scripted ways of rehearsing the activity before you begin. These scripts aren't a step-by-step lesson plan per se, but are rather a routine you might establish so that it is easier to try something new. For each chapter, a step-by-step lesson plan is available in the online resources that accompany this book (see composingscience.com).

Next come examples from our classroom that illustrate how this strategy is "taken up" by students. In other words: What do students actually do with their notebooks or with whiteboards? What does that look like in the classroom and how does it play out? How is the work of students related to the scientific practices that we hope to cultivate? Here we offer examples of our own students' work, drawn from the course Scientific Inquiry. The students we describe are majoring in Liberal Studies, a program designed for future primary teachers; in most cases, these are students who do not think of themselves as particularly skilled at science or interested in scientific research.

Much of the writing in our class is different from what students have experienced in science classes, and it takes a bit of scaffolding to orient them to these new routines. As we have discussed this course with colleagues, they have had a range of questions related to the routines. So we next discuss the "challenges", for students and faculty, that we have encountered and what we have done in response.

The next section, "feedback and marking", discusses ways to provide both formative feedback to your students and, more summatively, give them a mark for their work. To us, feedback and marking serve different roles. Feedback is akin to what might happen when you circulate a draft to colleagues or share ideas at a conference or other settings wherein you discuss your ideas prior to a more summative and formal journal submission. The feedback that students receive from faculty and peers is meant to help students develop their ideas further, consider other points of view and work on clarity in their representations. The feedback that students offer their peers is critical, too, as it is a way in which they deeply consider others' ideas, alternative representations and data they might not have noticed or considered. In this way, much of the feedback on student writing is performed by students; this mirrors scientific work, with the added benefit of reducing the instructor's workload. (Perhaps the most helpful piece of advice we received in talking with colleagues in composition was: "You don't have to touch every piece of writing. If you have time to give feedback on every piece of writing, your students are not writing enough.")

In contrast to feedback, marking is done by faculty and assigns a number to a student's writing, something that is qualitatively different from giving detailed feedback as part of the development of an idea. Marking is comparable to an editor making a decision on your paper, the NIH assigning a score to your grant, or a conference organiser deciding whether to include your presentation in the proceedings.

Finally, we summarise each chapter with some "take-home messages". Here we summarise the key themes from the chapter and provide concrete information that you can use right away.

## MECHANICS AND GRAMMAR

You can anticipate that your students will struggle with grammar, mechanics and other conventions as they learn to write in a new field. This does not mean that your students have not learned, for example, how to write persuasively or what constitutes a run-on sentence. Instead, as noted in Appendix A of the Common Core (2010), the course curriculum standards currently used in the United States, it often indicates that your students are learning a new and complex task:

> Grammar and usage development in children and in adults rarely follows a linear path. Native speakers and language learners often begin making new errors and seem to lose their mastery of particular grammatical structures or print conventions as they learn new, more complex grammatical structures or new usages of English, such as in college-level persuasive essays (Bardovi-Harlig, 2000; Bartholomae, 1980; DeVilliers & DeVilliers, 1973; Shaughnessy, 1979). These errors are often signs of language development as learners synthesise new grammatical and usage knowledge with their current knowledge. Thus, students will often need to return to the same grammar topic in greater complexity as they move through K–12 schooling and as they increase the range and complexity of the texts and communicative contexts in which they read and write.

However, as should be clear, this is not a book that suggests explicit methods of instruction in grammar and mechanics. And in fact, most writers, both newcomers and old-timers in any discipline, will never "master" the conventions of language, particularly since language is a living thing.

What we *can* do as instructors is give students plenty of opportunities to try out the writing practices in our field, share in the responsibility for teaching writing mechanics (especially noting when a particular convention is part of our academic genre) and, perhaps most important, model expectations about reading their own writing and the writing of others with care. As the field of composition and literacy studies has demonstrated, learning the mechanics of writing does not precede writing; we learn to edit our own prose over and over again as we work through complicated ideas. As students' ideas and arguments become clearer, their writing becomes clearer.