INTRODUCTION

WRITING SCIENCE FOR NEW READERS, WITH NEW TECHNOLOGIES, IN NEW GENRES

Science must have clear, persuasive voices. At no time in history has it been both more important and more possible for scientists to be able to influence public policy locally, nationally, and around the world. At the same time, science must remain true to its time-honored mission to seek the truth and to resist any temptation to come to easy conclusions at the expense of the careful, often tedious, unglamorous collection of data and open-minded analysis.

Meanwhile, advances in information and communications technology have provided science communicators with an astonishing range of styles, languages, and tools for carrying out the work of science and for sharing that work worldwide.

This introduction will lay out the rhetorical focus of this book: its recurring emphasis on the scientist-writer's obligation to fit the content of writing (the what) to the needs of a great range of readers (the who). Today's readers of science, technology, engineering, and math (STEM) possess great differences in knowledge, but they want to understand scientific breakthroughs and processes—and to use them for practical purposes toward ensuring human and environmental survival and success.

This introduction will also explain how twenty-first-century technologies have both broadened the audiences for science and brought about

new genres for science writing not before possible. Among these recent advances is the effective redefinition of writing as no longer limited to the conventions of alphabetic and mathematical language, but now able to exploit visual, aural, and kinetic capabilities for showing and explaining phenomena.

This book is for you, if

- You are a *practicing scientist* who needs to write one or more of the following documents: grant applications; project reports for supervisors or agencies; articles in research journals; laboratory or field research reports; summaries or reviews for non-scientist readers; posters and oral-visual presentations for meetings or conferences; blog posts for science or non-science readers; opinion or descriptive pieces for more popular venues such as newspapers, magazines, and broadcast media; advocacy articles for legislatures or government committees; multimedia documents (such as infographics) for popular audiences, etc.
- You are a *graduate student* who is part of a team or lab that needs to write any of the above documents, or who teaches or assists undergraduate STEM courses.
- You are a *non-fiction* or *technical writer* with an interest in science topics and in writing about science in blogs, newspapers, magazines, books, and other non-specialist venues.
- You are an *undergraduate college* or *high school student* with a serious interest in a STEM subject and who wants to communicate well in school and with other people as interested as you are.
- You are *anyone who loves science-relevant topics* and who wants to communicate your interests, discoveries, and ideas to others—but may lack confidence in your writing.
- You are a *teacher of a STEM subject* who wants to help students deepen their knowledge or wants to help students write better about their STEM topics.

Writing Science in the Twenty-First Century presents thirteen concise chapters (plus this introduction) that offer guidance and examples to help you succeed in a broad range of writing tasks and purposes, all pertinent to the work of science and other STEM fields. We emphasize the *twenty-first century* because writing about STEM topics is much more varied now than in the past and reaches perhaps a billion more people because of Internet and broadcast technologies.

"Writing" in this century is also very different from writing in the past: we now use pictures, sound, and video as well as words and numbers—and often in place of words. This book addresses in a concise way all these needs and opportunities that make science writing now more exciting and vital than it has ever been before.

A FOCUS ON SCIENCE, BUT RELEVANT TO ALL STEM

This book will take most of its examples and lessons from scientific fields, such as the life sciences, chemistry, physics, and geology, but some examples will be taken from mathematics and engineering, so those in all STEM fields should find the book relevant to them. The "Writing in Science" classes that my colleagues and I have taught over years have included students from a very wide range of STEM majors, including engineering disciplines, agricultural and environmental sciences, computer science, and mathematics, as well as fields such as chemistry, biology, and physics, not to mention the many majors that have developed as combinations of sciences and technologies.

Students also come from such majors as anthropology and psychology, which rely on methods, materials, and genres that have much in common with all other STEM majors. The principles, processes, and techniques this book describes have been useful to these students, and I hope you will find them useful, too, and perhaps even inspiring. Thus, when I refer to writing in science in this book, you should understand it in terms of this more-inclusive STEM context.

Here is the breakdown of chapters:

CHAPTER ONE: WRITING TO REACH READERS

This chapter illuminates the act of writing as a person's (or team's) striving to achieve effective communication with actual and very different people who want and need to understand the writer's message—and whom the person or team wants to influence. The chapter argues against the unprovable assumption by many scientists that "the data speak for themselves." The data can only be as powerful as the writers and speakers who interpret and explain them.

By looking at contemporary examples from both peer-reviewed and more popular science writing, this chapter shows how effective science writers craft their writing to relate to the interests of their readers. Specific tools and techniques will be described—including a **systematic method** of both reading and writing with rhetorical awareness.

CHAPTER TWO: BUILDING EXPERIENCE AND CONFIDENCE IN WRITING SCIENCE

This chapter is meant mainly for students and their teachers, but can be used by anyone who wants to boost writing confidence. Among tools to be explained will be **writing to learn** in science, and other powerful techniques of learning and thinking for the student. The chapter will describe typical obstacles for student writers in STEM fields, and how writers, often with teachers' help, can overcome them.

In particular, this chapter shows how easily accessible online tools and services, from Twitter to Facebook to reader-response forums and blogs, can help writers develop fluency and confidence to take on greater challenges.

CHAPTER THREE: "WRITING" REDEFINED MULTIMODALLY

Using examples from recent digital and print sources, including peer-reviewed journals, this chapter describes ways that effective science communicators have augmented conventional letters and numbers with visual language (e.g., photographs), aural language (sound files), video, animation, and links to outside sources. The new dominance of digital, Internet-based STEM communication over the print paradigm will be a major theme.

This newly and more broadly defined writing is becoming essential to science communicators. The chapter begins a process of showing writers easy ways to integrate some of these tools into their writing, and how to do so with rhetorical effectiveness. This process will be further elaborated in Chapters Eight through Eleven.

CHAPTER FOUR: WRITING SCIENCE ETHICALLY

While ethical conduct in the pursuit of scientific advances will be noted from time to time throughout the book, this chapter pays particular attention to ethical conduct in ways particularly pertinent to science writing and overall communication. As scientists gain greater access to broader publics through the Internet and new genres, science writers contend more and more with how to resist the urge to overclaim the importance of their work. They contend with acknowledging the limitations of their methods in the face of (1) stringent competition for scarce funding and (2) opposition from those, often hostile to science, who never hesitate to expound their points of view, with little regard for accuracy.

Accurate citation of sources, when and how often to cite, how fully to report methods, how to realistically measure the importance of results, how to realistically make claims about the implications of one's research—each of these concerns will be concisely explored in this chapter and advice given.

CHAPTER FIVE: WRITING THE RESEARCH ARTICLE, PART I—ABSTRACT, INTRODUCTION, AND METHODS AND MATERIALS

Because publication in peer-reviewed journals is still the gold standard for academic research scientists, two chapters consider the conventional introduction-methods-results-discussion (IMRD) research article and offer advice on making the most of the opportunities the form gives to write clearly, accurately, and persuasively. Looking at excerpts from influential articles in such journals as *The New England Journal of Medicine* and *Science*, this chapter shows how reader-oriented writing can both be persuasive and adhere to strict standards of precision. Chapter Five will focus on abstracts, introductions, and methods and materials as part of the IMRD form.

CHAPTER SIX: WRITING THE RESEARCH ARTICLE, PART II—RESULTS AND DISCUSSION

This chapter will continue the pattern established in Chapter Five, but will focus on the writing of results and discussions. It will consider new patterns in citation (e.g., links to sources) and graphic display that can make journal writing more effective in reaching readers, among other recent stylistic innovations brought about by online publication tools and capabilities. In addition, this chapter (and Chapter Five) will consider ways in which the different sections of the IMRD format can be tailored to the needs and characteristics of different types of readers.

CHAPTER SEVEN: WRITING THE RESEARCH REVIEW

For both working STEM professionals and STEM students, reviews of research are essential tools in both understanding scientific inquiry and communicating the importance of any path of research. Not only is the review of research an essential aspect of all IMRD articles (in the Introduction of the report), but the research review is also a major form in its own right in the peer-reviewed literature.

This chapter offers advice for making the research review a purposeful, persuasive, and reader-focused work that demonstrates the writer's ability to summarize, paraphrase, and quote other researchers accurately and forcefully. It calls for an awareness of the history of science and the ability to probe how ideas change in science. In this chapter, the review of research moves way beyond the summary of key studies to become a tool to shape the significance of research and forge paths for new research.

CHAPTER EIGHT: STEM JOURNALISM—WRITING, READING, AND CONNECTING WITH BROADER AUDIENCES

This chapter describes the huge growth in popular (non-specialist) science writing in print and online magazines, newspapers, and websites. Examples from newspaper websites and from popular STEM magazines (print and online) such as *National Geographic* and *Scientific American* will be featured to illustrate ways in which STEM writers can learn to communicate with broader audiences and in ways attuned to today's multimodal expectations and tools.

The chapter also spells out some of the implications of broader global accessibility, and what these mean for science communicators. The most profound changes have been the global broadening of the audiences for science communication and the formation of new genres and styles enabled by tools and influences from social media.

Although the peer-reviewed IMRD article and the research review are established forms in traditional print publishing, they, too, have been influenced by the emergence of new technologies and their capabilities, as well as by the global reach of the Internet. The chapter will include tips on voice, genre, and organization, as well as writing vividly to attract and maintain readers.

CHAPTER NINE: SCIENCE BLOGS—NEW READERS, NEW VOICES, NEW TOOLS

Science blogs have become prolific in all fields and have become a common way by which new ideas—and new voices—in science have been recognized. These blogs are either stand-alone sites by individuals and research teams, or interactive adjunct sites to established companies, journals, and agencies. New styles, including freer use of first-person point of view and multimodal capabilities, have made blogs experimental sites for science communication. This chapter offers insights and advice for making the most of these opportunities.

CHAPTER TEN: CREATING POSTERS AND INFOGRAPHICS

Poster presentations at academic conferences are a traditional way for displaying research in a highly visual, but condensed, format. Posters enable text, but they feature emphatic graphics, usually charts and diagrams, often colorfully. This chapter explores creation of effective, varied poster formats, but goes beyond this traditional genre to open up exploration of the poster's more versatile, online cousin, the *infographic*.

Infographics have become increasingly popular to display research results in a condensed visual format. Where text is still the primary tool of the poster, the infographic emphasizes the visual, though it can still display

a surprisingly large amount of text. The infographic has the capability of linking to larger textual explanations—and other visuals.

CHAPTER ELEVEN: CREATING ORAL-VISUAL PRESENTATIONS

Scientists' ability to give oral-visual presentations is an integral part of their ability to communicate with audiences of all kinds. PowerPoint and Prezi presentations are standard at conferences and meetings, as well as becoming more and more common as alternatives to straight textual presentations online. This chapter offers advice and models not only for making the visual aspect of presentations stronger, but also emphasizes and strengthens the interactive relationship of the speaker and the audience.

CHAPTER TWELVE: WRITING SCIENCE WITH STYLE AND STYLES

Science writing is caricatured as "dry" (parched? drought-stricken?) and boring—yet many scientists and journal editors are willing to accept this criticism out of the mistaken, counterintuitive notion that interesting writing equals lack of objectivity, therefore careless, imprecise research. But writing that bores is more often a sign of lack of care to communicate clearly. It may indeed cover up shoddy methods and thinking (which readers are too confused by to investigate!).

This chapter digs into common stylistic problems with science prose—cluttered paragraphing, confusing organization, too much jargon, too many irrelevant numbers—and offers simple methods to make the science researcher's prose as interesting as the work and ideas themselves.

CHAPTER THIRTEEN: EDITING SENTENCES

While a scientist takes great care to keep a worksite clear, clean, and ready for work, sentences in science prose often can't do their work because meaning is hidden by lazy writing. This chapter puts sentences in sharp focus and offers tips for editing syntax, voice, length, tone, and word choice to make meanings stand out. *Editing* of sentences is distinguished in this chapter from the crucial work of *revision*, by which writers modify their ideas and presentation throughout the process of writing to make it more effective.

WRITING RHETORICALLY: CENTRAL TO EFFECTIVE STEM COMMUNICATION

Throughout this text, I will use the terms "rhetoric" and "rhetorical" to talk about the process by which researchers and other writers can successfully communicate their ideas to the readers important to them. Why is rhetoric so important to science? How can it be most usefully understood?

Let's begin with a thought experiment that I call "Confronting the Rhetorical Wall."

> Think about the scientific topics that you are most interested in. Think about the work you do and the work by others that you read. Now think about the people to whom you have spoken about these interests and about what you have read. How would you characterize these people? What do they have in common? How are they different? Are some of them easier for you to talk with than others? Why?
>
> Are there some people you avoid talking with about your work because (1) they have a different point of view about the subject than you do, or (2) explaining what you do and why you do it would be so hard for them to understand that you feel it's not worth the effort?
>
> Are you ever frustrated to realize that some of the people whom you **most need to convince about your work** are in one or both of those categories? Do you ever retreat back into your lab or field site to run another test or take more samples or make more observations because you don't want to think about those frustrations?

If so, then you have run up against what I call a "rhetorical wall." Rhetoric is an ancient idea that more or less means the art and science of persuasion through less violent methods than a bang over the head or an arrow through the heart. The Greek philosopher Aristotle (2006) wrote about rhetoric more than 2300 years ago, but even then the need for rhetoric was very ancient.

Rhetoricians have been writing about non-violent persuasion ever since, as cultures have changed and technology has advanced. The tools of rhetoric are mostly language—words and numbers spoken and written—but they also include any other means that sentient beings, not only humans, can call on to get other sentient beings to do what they would like them to. Sex appeal is a powerful rhetorical tool. So is how people dress and adorn themselves. So are pictures and fragrances and music and physical demonstrations. Anything that gets one creature to pay attention to another for a purpose of persuasion is rhetoric.

THE DANGERS OF RHETORIC

Because rhetoric is so powerful, it is incredibly dangerous. The people who have been most successful in the world—whether for good or for evil—have tended to be good rhetoricians. But rhetoric does not require truth to be effective, merely the appearance of truth. Thus, for good reason, many

who love science distrust, even hate, rhetoric for how it has been abused. Because science is the dogged pursuit of truth, many scientists abhor the idea that scientific truth—what can be proven through rigorous testing—is usually not persuasive in itself, but instead needs to be "dressed up" in a way that makes it attractive to others, including other scientists—not to mention all those who have never actually studied what they nevertheless passionately believe.

While, for example, almost all environmental scientists think it should be obvious that humans have caused climate change in the twentieth and twenty-first centuries, because test after test shows this to be so in numerous settings, polls show that a third of the people in the US refuse to accept the idea of human-caused climate change, and way fewer than half actually act in their daily lives as if this truth mattered.

Why is this difference between scientific truth and widespread belief and behavior so drastic? And why do scientists who wish to have some impact on public policy and public behavior need to understand this difference? In other words, why do scientists need to learn rhetoric?

WHY SCIENTISTS NEED TO LEARN RHETORIC

The most common assumption among scientists about this disjunction between scientific truth, popular belief, and behavior is that the broader public is not smart or educated enough to grasp scientific consensus. Part of the fear of rhetoric in the scientific community is that researchers will need to "dumb down" the language of science in order to communicate with non-specialists—and thus will inevitably oversimplify their work and its subtleties. Certainly, oversimplification is a danger when a message is shortened for audiences not interested in the mass of data *nor* details of methods *nor* the range of opinions on a question *nor* the history of research in an area of inquiry.

For example, oversimplification has been a particular difficulty in pharmaceutical research, wherein the painstaking, years-long processes of research and the intricacies of clinical trials have often been reduced by advertisers and mass media to dramatic claims of breakthroughs—or "scare stories" about the supposed dangers of certain treatments. (The furor in some states about the alleged link between childhood immunizations and autism is an excellent example of such a scare story.)

Later, Chapter Four on "Writing Science Ethically" focuses on the temptations to scientists themselves to *exaggerate the value* of research or its applicability in order

- to secure funding from public or private sources, or
- to draw attention within the science community.

Whatever the reason for the oversimplification of science, the problem is *not* dumbing down to a less educated audience as it is misleading audiences that could—and should—be trusted to understand a more cautious, less one-sided message. That trusting audiences can work is shown by the success of systematic nutrition labeling on food products over the past thirty years, which has drastically changed consumer—and producer—behavior. Systematic labeling has demonstrated the ability of consumers—when given access to diverse products—to make choices based on more complex information.

Chapters Eight through Ten will expand on this need to reach broader, non-specialist audiences with accurate information that is presented with respect for the intelligence and knowledge of diverse groups of readers.

Learning rhetoric so that one can reach different audiences should better be thought of as

1. Working to understand why different audiences need different information, and
2. Learning how to use different *language*, *media*, and *argument strategies* to meet those different needs.

WRITING AND SPEAKING WITH RESPECT FOR DIVERSE READERS

An attitude of respect for diverse audiences is more realistic than an attitude of contempt. Recognizing that *certain audiences have greater expertise* in some crucial areas than do the researchers will go a long way toward helping scientists succeed in reaching those audiences. For example, a key purpose of government scientific research agencies is to provide evidence to legislative and executive committees as they ponder proposals to change laws on such issues as health, water, energy, parks, roads, and public safety. Indeed, it's difficult to think of an area of government where scientific thinking and study are not important.

But scientists often lack the knowledge that lawmakers and staffers have of the greatly varying concerns of different groups of voters. Scientific data collection and analysis that meets priorities of the researchers is often doomed to be thought irrelevant—if the scientists-writers are not aware of the needs and concerns of the policy makers and their constituents.

For example, publishing in-house technical reports on an agency website meant for voters and legislators will most likely confuse and bore, unless those reports are carefully introduced and summarized in a way that addresses the concerns of the readers. Moreover, if even highly relevant research is presented only in the numerical and theoretical languages of the scientists, then the relevance of the research will never be seen and surely not

used. It is tempting for scientists to criticize the inability of non-scientists to read scientific discourse and theory, but if budgets are cut for scientific research because of the lack of persuasive communication with the people who fund those budgets, then blame is poor compensation.

EFFECTIVE TOOLS FOR STEM RHETORICIANS

Fortunately, contemporary science journalism offers us many, many examples of highly effective writing that bridges the gap between the languages of the lab (and the specialty journals that speak them) and the constituent groups responsible for bringing knowledge of real concerns and human situations to policy questions. Periodicals such as *National Geographic*, *Catalyst*, and *Scientific American* have different missions, but each reaches a broad audience of readers, most of whom are not science researchers but all of whom have varying levels of interest and knowledge in science topics. In addition, major newspapers such as the *New York Times* and *Washington Post* routinely publish both online and print versions that include science-relevant articles on a daily basis.

Science journalism is a profession that has burgeoned in the past three decades, and which includes not only many skilled writers, but outstanding photographers and, more recently, digital designers. Chapters Eight through Eleven will particularly study methods used by these writers, designers, and editors.

But even the peer-reviewed research journals themselves are changing (slowly) in response to access by larger online audiences—and by the awareness that science communication needs to become more rhetorically effective for science to succeed. Chapters Five through Seven focus on this need to change and how it can happen.

In the chapter (Chapter One) that immediately follows this introduction, we will look more intensely at the process of reaching readers with your writing: scaling that rhetorical wall for audiences of different perspectives and kinds of knowledge.