

GERALD RAU

**WRITING FOR
ENGINEERING AND
SCIENCE STUDENTS**
Staking Your Claim



Writing for Engineering and Science Students

Writing for Engineering and Science Students is a clear and practical guide for anyone undertaking either academic or technical writing. Drawing on the author's extensive experience of teaching students from different fields and cultures, and designed to be accessible to both international students and native speakers of English, this book:

- Employs analyses of hundreds of articles from engineering and science journals to explore all the distinctive characteristics of a research paper, including organization, length and naming of sections, and location and purpose of citations and graphics;
- Guides the student through university-level writing and beyond, covering lab reports, research proposals, dissertations, poster presentations, industry reports, emails, and job applications;
- Explains what to consider before and after undertaking academic or technical writing, including focusing on differences between genres in goal, audience, and criteria for acceptance and rewriting;
- Features tasks, hints, and tips for teachers and students at the end of each chapter, as well as accompanying eResources offering additional exercises and answer keys.

With metaphors and anecdotes from the author's personal experience, as well as quotes from famous writers to make the text engaging and accessible, this book is essential reading for all students of science and engineering who are taking a course in writing or seeking a resource to aid their writing assignments.

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Writing for Engineering and Science Students

Staking Your Claim

Gerald Rau

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Preface

Every year over 80,000 bachelor's degrees and 50,000 graduate degrees are awarded in engineering in the US alone, and three times that number in science. Worldwide the number is obviously far higher. Because of increasing globalization, many of those graduates must learn to write in English.

Textbooks on scientific and technical writing frequently provide prescriptive models, with templates for different tasks. While these make teaching and grading easy, and students using such texts may excel in class, that does not guarantee success in the real world. Considering the audience and goal will allow a writer to choose which common components of academic writing need to be included in a document, and an understanding of argument structure can guide how to place them. Thus the goal of this text is to provide basic principles that can be applied to any writing task.

The diversity of my training and work experience has played an important role in shaping this textbook. My doctoral degree was in natural science, but I later returned to get a master's degree in science education, so I saw how different writing styles are in the natural and social sciences. While working as a science teacher I wrote lesson plans, lab and classroom activities, various reports, SWOT analyses, and a school accreditation self-study. When a local company was bought by an international corporation, I helped them learn to write email and technical reports to communicate effectively with their new headquarters in the US. My own writing experience has included journal articles, articles for a science teacher magazine, book chapters, and a book. Moreover, my work as a freelance academic editor for over 15 years exposed me to research journal articles from a broad range of disciplines, from linguistics to medicine to applied mathematics, as well as other genres such as grant proposals.

Thus when I was asked to teach academic writing I knew that the structure of articles differed considerably across disciplines, but I believed that engineering used the same basic IMRD (Introduction, Method, Results, Discussion) format as the natural sciences. After all, scientists tend to think of engineering as "applied science." When one engineering student after another said none of their research articles followed that format, I began my own investigation. When my analysis did not match what I had read in textbooks on academic writing, I started to develop my own teaching material.

I have now taught academic writing for seven years, first in the learning center and currently in the electrical engineering department at National Chung Cheng University. My students have come from many branches of engineering, including electrical, mechanical, chemical, and computer science and information engineering, as well as various fields of

science and social science. Their analysis of articles in their own fields formed the basis for the general components proposed in this textbook. Combining that knowledge with the principles of argumentation and knowledge construction that underlie modern science education allowed me to generalize and extend the concepts to other types of writing.

This book presents a new general framework for understanding academic and technical writing, particularly in science and engineering, based on the premise that all such writing is argumentation. For academic writing, I claim that although the widely accepted IMRD model is useful in science, it is of limited value for engineering. Support for that claim will be found in the chapters that follow. I further claim that if students learn basic principles of argumentation, learning to think in terms of claim and support, they can become more effective communicators in any genre, written or spoken, as supported by the testimony of former students.

To the student

Many books on science and engineering writing follow a “one-size-fits-all” approach, giving the impression that every field uses the same basic format, and teaching you to write that way. Unfortunately, journal articles in engineering *do not* follow the textbook format for journal articles in science, and there is a lot of variation between different disciplines, and even subfields within a discipline. The same could be said for any other type of writing.

Thus this book approaches writing from a genre analysis perspective, which simply means learning to write like someone *in your field* by analyzing good examples of writing *in your field*. It provides step-by-step instructions through various stages of the writing process, with examples and practice exercises. The book will be most useful if you have a competent mentor to check your work, either an instructor in a writing course or an academic advisor (or preferably both), but can be used for self-study as well.

Since I have lived in Taiwan for most of the last 25 years and most of my students have been native speakers of Chinese or other Asian languages, the text naturally addresses the needs of those whose first language is not English. Additional material for those using English as a lingua franca may be found on the publisher’s website. Nevertheless, since no one uses academic English as their first language, any novice writer should be able to benefit from the ideas presented here. I hope you will find the book useful.

To the teacher

There are several new ideas in this book that have never been published before, although some will be appearing in journals and a book chapter at about the same time. The first is the proposal of IPTC (Introduction, Process, Testing, Conclusion) as a way of naming the prototypical format for engineering research articles, based on my own analysis of articles in engineering journals. As I will explain, the focus of an engineering article is on developing and testing a new design to solve a problem, rather than on explanation of data to answer a question. This is reflected in an argument structure and topic placement that differs from the traditional IMRD format of scientific papers. I also propose the 7Cs of Change, which evolved gradually through several years of teaching stepwise revision of academic writing. The chapter on email likewise contains novel ideas related to well-known sociolinguistic and pragmalinguistic principles.

Applied linguists will find that sometimes I do not follow standard terminology in the field. Since I am not a linguist by training, the first draft of the book was written before I realized I was in many cases reinventing the wheel. Even after reading the linguistics literature, I have chosen in some cases to retain my own terminology. Because this book is written for science and engineering students, I have tried to use terminology they will readily understand rather than the fine distinctions teased out by linguists over the years. In the notes you will find the standard linguistic terminology and references to some of the seminal works, in many cases published decades before I stumbled on a similar concept. Where my analysis differs from previously published work, often based on analysis of texts from engineering that do not match previous studies of research articles in science, this is also discussed in the notes, since it is of more interest to teachers than students.

A grant from National Chung Cheng University allowed me to hire research assistants to confirm many of my preliminary findings, but there is still much to be done. Relatively little linguistic analysis has been conducted on the structure of engineering research articles or technical reports, so this text should by no means be considered the final word. Rather, it is my hope that this work will stimulate further research by providing a productive framework to test and modify. Any exercise in this text, conducted on a selection of journal articles from one field or journal, or a corpus from a certain business or industry, would provide a suitable topic for a paper or thesis in applied linguistics. Comments from engineers are also highly welcome, whether to correct misconceptions, make the categories clearer or more useful, or expand the work to other areas. If you have any suggestions on how the book could be improved, please let the publisher know and

I will very happily correct any mistakes, give better examples, and cite your research or comments in any future editions.

This text is too long for a one-semester class. Proposed syllabi and suggestions on how to use the text in basic and advanced classes may be found in the supplemental teaching materials on the publisher's website. On the website you will also find PowerPoint summaries of each chapter and additional exercises and materials to assist those using English as a lingua franca. Teaching tips in each chapter give suggestions on how to make your class more successful, based on my experience. This book works very well with a flipped-classroom approach, where students read the textbook at home and come to class to do the exercises and homework. This allows you to catch problems quickly, resulting in less frustration for the students and less correcting for you.

Finally, note that the book is primarily addressed to students, not teachers. In many cases I will address the reader as "you," referring to the one learning to write. It is my intent to come alongside them, as much as is possible given the medium, acting as a mentor and sharing anecdotes from my own experience rather than providing dry formal pabulum that they would dread reading.

Acknowledgments

First and foremost, my appreciation goes to my wife, D. Victoria Rau, a Professor in the Institute of Linguistics at National Chung Cheng University, who identifies herself as an applied linguist although much of her work is in Austronesian linguistics and sociolinguistics. She pointed me to the books of Swales and Feak and urged me to pursue this work. Without her, it would never have gotten off the ground.

Students in my classes over the years have contributed to my knowledge of academic writing in their fields and pointed out where what I said in class did not match what they saw in their exemplar articles. From the engineers who took my first writing class (when I still thought that engineering followed the IMRD format) to the present, their questions and comments have caused me to question and improve my analysis and clarify both the writing and the exercises.

Work on an early draft of this textbook was partially supported by a teaching material development grant from the Ministry of Education, 2016 Teaching Excellence Program, administered by National Chung Cheng University (榮獲105年度教育部獎勵大學教學卓越計畫及國立中正大學補助). The grant allowed me to hire three graduate assistants, Vithong Nguyen from the Institute of Linguistics and Wei-Young Chen and Jin Tsung-Hsin Liu from the Department of Electrical Engineering, to confirm and refine my preliminary analysis of various aspects of engineering articles. Jennifer Kuo, a very capable undergraduate in linguistics at Dartmouth College, also assisted with the work and contributed important ideas to the book and related articles that will appear. Without them, the task would have been far more difficult.

Christine Feak provided encouragement and helpful comments on an early draft of this work. John Blake was willing to use a draft copy of this book in his class on thesis writing at the Japan Advanced Institute of Science and Technology and offer feedback. Yun-yin Huang, Anita Pu, Ching-Yen Ellie Yu, and Tetyana Smotrova, writing instructors who attended my workshop at ROCTEFL 2018, also provided important encouragement and suggestions. Please accept my thanks.

Francesca McGowan, my editor at Taylor & Francis, was willing to support a proposal from an unknown author, and Elizabeth Cox, her capable editorial assistant, handled many of the details of the process. I am also indebted to the five anonymous reviewers of the project whose comments led to its approval, as well as all the members of the copyediting and production teams. The diagrams and flowcharts in the book were drawn by Romer Valera.

Various works by Swales and Feak provided an introduction to genre analysis, as well as many of the linguistic terms, as will be seen in the numerous citations. The approach

taken in this book is very similar to that of Cargill and O'Connor (2013), and I have benefited from reading their work. Although the first draft was complete before I heard of theirs, during the revision process I have combined some insights from their work with my own observations, and cited places where they had already published similar ideas.

Thanks to various publishers for permission to use previously published graphics, including Oxford University Press (Table 7.2), John Wiley and Sons (Table 24.2), and the Seismological Society of America (Table 24.3). Thanks also to Gregory T. Kleinheinz et al. for permission to reprint the Open Access article "Effects of rainfall on *E. coli* concentrations at Door County, Wisconsin beaches" in the Sample Component Analysis, as well as to InterVarsity Press (US and UK) for permission to quote from my previous book, *Mapping the Origins Debate*, in Class Exercise 21.3 (both in the online supplemental material).

Undoubtedly there are many other works in the field that should have been cited, ideas that I pulled from various sources and used in my teaching before I decided to write for publication. I have tried to track them down, but undoubtedly have missed some. Any oversights are unintentional, and any remaining errors my own.

Many thanks go to my blind masseur at Siloam Helping Hands who saved my neck (and back, and shoulders) multiple times along the way. Finally, special thanks to El Shaddai and the nurses and doctors at Dalin Tzu Chi Hospital, without whom I would not have been able to see this book to completion.

Reference

CARGILL, M. & O'CONNOR, P. 2013. *Writing scientific research articles: Strategy and steps*, New York, John Wiley & Sons.



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Part I

Getting the big picture



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General principles of writing

1.1 Fitting in, standing out

I currently teach at a university in a rural area in southern Taiwan. There is no written dress code, but almost everyone dresses informally. Students come to class in shorts and tee shirts, with sneakers or flip-flops on their feet. It just seems to fit the area. Someone wearing high heels and the latest fashion would seem out of place, perhaps a visitor from elsewhere. They just don't fit. But among the informally dressed students, some stand out. They ask the right questions, work hard, and excel in class.

The same principle applies to writing in science or engineering, whether in academics or industry. For example, there may not be a written code that says what a research article should look like in your field, but everyone who has been in it for a while knows the unwritten rules. If you follow those rules, you will fit in. If not, they will look at you like an outsider, and your paper is less likely to be accepted. But within those papers that all look similar, some stand out. They ask the right questions, are well written, and wind up being highly cited. Nevertheless, if you don't fit in, you never get the chance to stand out (Figure 1.1).

The problem is that when you begin to write in a new field of study, you do not know the expectations, the unwritten code. I suggest there are three ways to learn the unwritten expectations in your field:

- (1) Gradually learn by experience;
- (2) Ask someone with more experience;
- (3) Purposefully study the structure of successful writing.

Many students choose the first route, often by default rather than active choice. They finish their research and are ready to write, but then realize they have no idea how to structure their writing. Nevertheless, they try their best, and wind up very discouraged when their teacher or advisor says they have completely missed the mark. After a number of attempts, they finally succeed, and after a few more attempts manage to master the style. Nevertheless, they may not be able to describe it to others because they have never considered what makes some writing better *structurally*, only in terms of content. This is also the limitation of the second route—some professors can train their students to do the research but have never studied or thought critically about how to write.

That brings us to the third route, and the purpose of this book. Every journal has its own unwritten rules that define the expected structure for articles, and you must learn

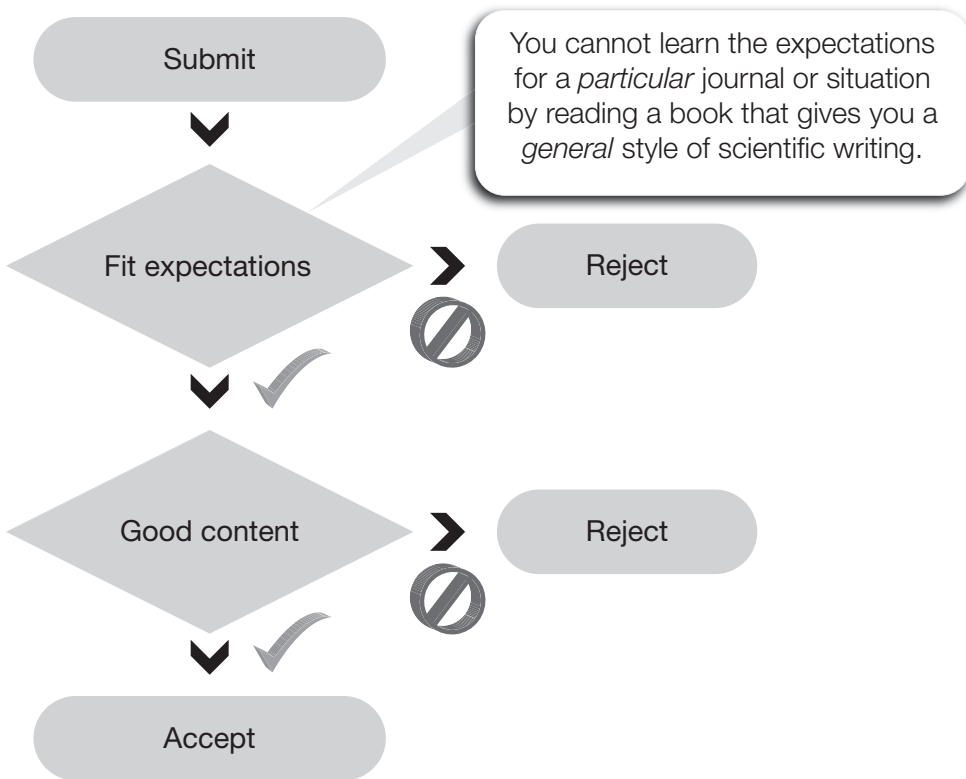


Figure 1.1 Fitting in and standing out.

what those rules are if you want your work to be accepted by that journal. Every business has similar unwritten rules for reports in that company. You cannot learn the expectations for a *particular* situation by reading a book that gives you a *general* style for a certain

The method taught in this book allows you to write better, with less revision, and easily adapt your writing to meet the expectations of different situations.

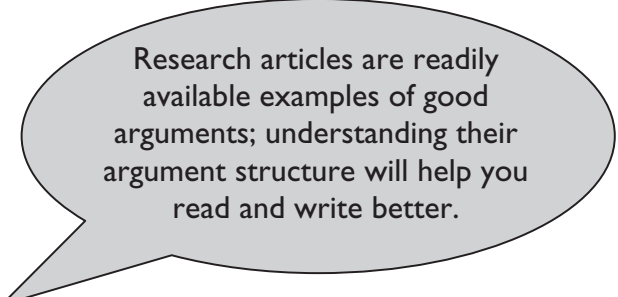
type of writing. You can do it by reading and working for many years and gradually assimilating the style, or you can expedite the process by actively studying the structure of good examples. In this book you will learn and practice how to do that.

The process initially will seem very tedious. At first you may wonder if it is worthwhile, but it has two advantages. The first and most immediate is that whatever documents you need to write as a student will require less revision and get higher marks,

because they meet the expectations. The second and ultimately more important is that it will be easier to adapt your writing to different situations. After using the method to purposefully study journal articles, you can compare any subsequent writing task with what you already know. By noting the differences, you will be able to adjust your style of writing accordingly. If you have learned to write in one format by trial and error, you will have to use the same slow method for the second as well.

1.2 We have to start somewhere, but why research articles?

No matter what you want to learn, it pays to start with the fundamentals. Therefore, no matter what you plan to write first, we will begin with an analysis of research articles. There are four good reasons for this:



Research articles are readily available examples of good arguments; understanding their argument structure will help you read and write better.

- (1) You will learn to *read more effectively* to get the information you need to work in science or engineering;
- (2) Research articles are *complete arguments*, thus a good example for your own writing, but also part of an ongoing research effort;
- (3) Other genres of student and technical writing are *predictable modifications* of research article structure in that field;
- (4) Research articles are *readily available*.

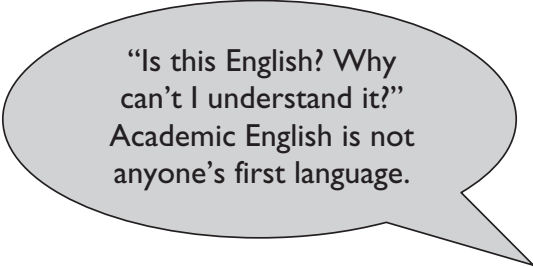
What the American novelist Stephen King said is no less true for academic writing than fiction: “If you don’t have time to read, you don’t have the time (or the tools) to write. Simple as that” (King, 2000: 147). Whether in school, academics, or industry, you will need to read research articles to get up-to-date information on the latest advances in your field. As we will see, research articles have a relatively predictable order of claims. Articles include most of the components common in science and engineering writing, and certain phrases are frequently used to mark each component. Understanding that structure and recognizing those phrases will help you locate the information you need for your own work more quickly and efficiently.

Although each research article stands alone as a complete argument, it is also part of the growing body of knowledge in that field. Thus each article is one link in a long chain of research and makes sense only in the context of that whole chain. You will need to read many articles before you can see the overall structure of that chain and understand which links are most important in holding the whole chain together, and which merely connect one item dangling from that chain like a charm on a bracelet. The same is true for technical reports, email, or any other type of writing discussed in this book.¹

Furthermore, as we will see in Chapters 10–17, although other genres make different basic claims than journal articles, they include many of the same components, evidence, and reasoning and are strongly influenced by the research article structure in that field. Thus understanding the structure of journal articles will assist you with almost any type of writing.

From a practical perspective, research articles are easy to obtain. Although it is difficult to access authentic examples of industry reports, grant applications, reference letters, and many other genres because of confidentiality concerns, there is a virtually inexhaustible supply of journal articles available in any field.

1.3 Academic English: a new language



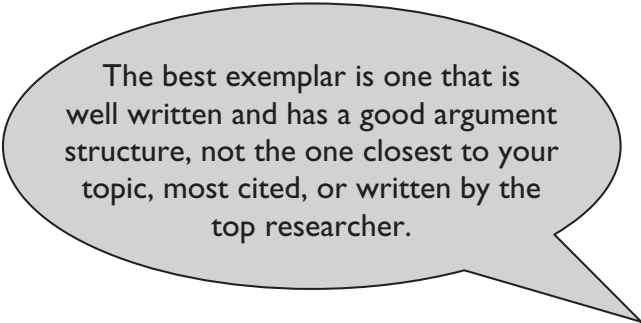
**“Is this English? Why can’t I understand it?”
Academic English is not anyone’s first language.**

If you are a graduate student, or even an upper-level undergraduate, you have probably read an academic journal article. What was your first impression? Many students, even those whose first language is English, wonder, “Is this English? Why can’t I understand it?” The language used in journals is very different from the language of everyday speech.

Linguists (those who study the structure and use of language) tell us that there are many different genres of writing. Genre refers to a specific category of written, spoken, musical, or artistic presentation, and each genre has its own style. Academic English is different from everyday English, and each discipline even has its own discipline-specific English, with its unique vocabulary and expressions. Technical writing is not the same as academic writing in the same field. The technique we will be using in this book is based on genre analysis. It will help you learn to both read and write academic and technical English, particularly the discipline-specific English of your field.

Since academic English is not a first language for any of us, this book should be useful to any beginning writer. As with learning any other new language, it will take time, but the principles taught in this book will help you improve faster. Eventually you will learn to not only write but also think in the patterns expected in your field.

1.4 Identifying good exemplar articles



The best exemplar is one that is well written and has a good argument structure, not the one closest to your topic, most cited, or written by the top researcher.

Throughout the book you will be examining exemplar articles. As the name implies, you can use exemplars as examples when you do similar writing, so it is important to identify which documents will be good examples. A good exemplar article is not necessarily the one whose content is the closest to your topic, or the most cited, or

one written by the most famous researcher in the field. The most-cited papers often lay out a new theoretical framework or methodology, and therefore may use a different format than