How to Write a Paper

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Introduction

This brief manual gives guidance in writing a paper about your research. Most of the advice applies equally to your thesis or to writing a research proposal. The content of the paper reflects the kind of work you have done: experimental, theoretical, computational. I have used, as a model, a typical Materials project: one combining experiment with modeling and computation to explain some aspect of material behaviour.

Sections 1 to 8 give guidelines for clear writing with brief examples. The Appendix contains longer examples of effective and ineffective writing. The manual is prescriptive—it has to be, if it is to be short. It is designed to help those struggling with their first paper, or those who have written several but find it difficult. Certain sections may seem to you to be elementary; they are there because, to others, they are not. Section 8, on Style, is open-ended, the starting point for more exciting things.

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1 THE DESIGN

Well-written papers are read, remembered, cited. Poorly written papers are not.

To write well, you need a design. Like any design activity, there are a number of steps (Figure 1). I've used the language of engineering design here—it fits well.

The Market Need. What is the purpose of the document? Who will read it? How will the reader use it? The answers help you decide the length, the level of detail, the style.

The Concept. Good writing starts with a plan. Writers have different ways of developing plans. I find the concept-sheet (Section 3, below) is a good way to do it.

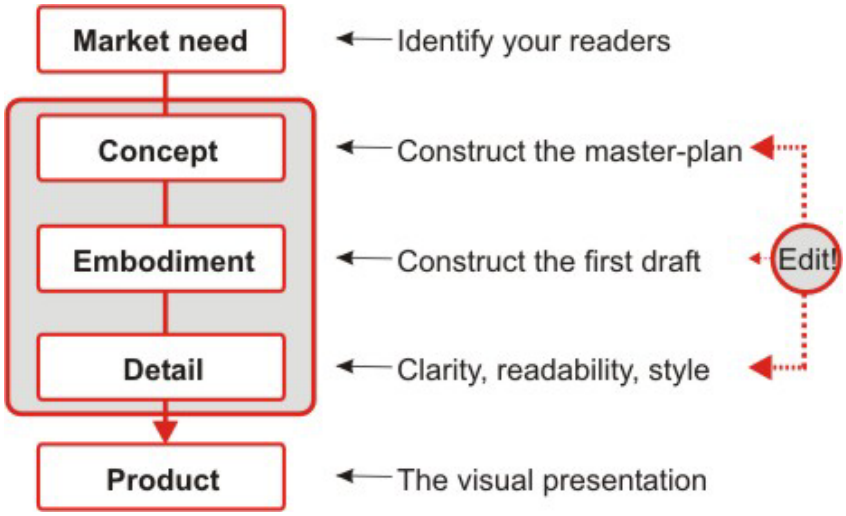


Figure 1. The Design Process. Designing a paper is like designing anything else: there are five essential steps.

The Embodiment. The embodiment is the first draft. Get the facts down on paper without worrying about style; make drafts of each section; develop the calculations; sketch the figures; assemble

references.

Detail. Now comes the crafting: clarity, balance, readability; in a word —*style*.

The End-Product. Appearance *is* important: good layout, clear headings, well-designed figures.

The Sections that follow expand on each of these in turn.

2 THE MARKET—Who are your readers?

Your market is your readers. Put yourself in their shoes: what, if you were they, would you wish to find?

The readers of your *thesis* are your examiners. They expect details of all relevant parts of your research: why you did it, its background, your thinking, what you did, your conclusions and your views on where it is going. They **don't** want the irrelevant parts—details of how standard equipment works, for instance. Find out as much as you can about content and format from your supervisor and other students, and look at some recent (successful) theses to get a feel for the product this market expects.

A *paper* is read by one or more skilled referees, and, if accepted, by a scientifically-informed audience. This manual focuses on writing papers. The pages that follow explain how this market should be addressed.

A *research proposal* usually addresses two markets. One is the funding agency: the EPSRC, the EU, another Government Agencies, or a Charity. They will look for a match between their priorities and yours. The other is the referees that the funding agency will use; they are charged with judging quality, promise

and relevance.

Hardest to write is a *popular article*, addressing an audience who is intelligent—one should always assume that—but who may know nothing of your subject. Here style, always important, must be fine-tuned to meet their needs. More on style in Section 8.

Make no mistake. Write poorly and you'll bore, exasperate and ultimately lose your readers. Write well, and they'll respond in the way you plan.

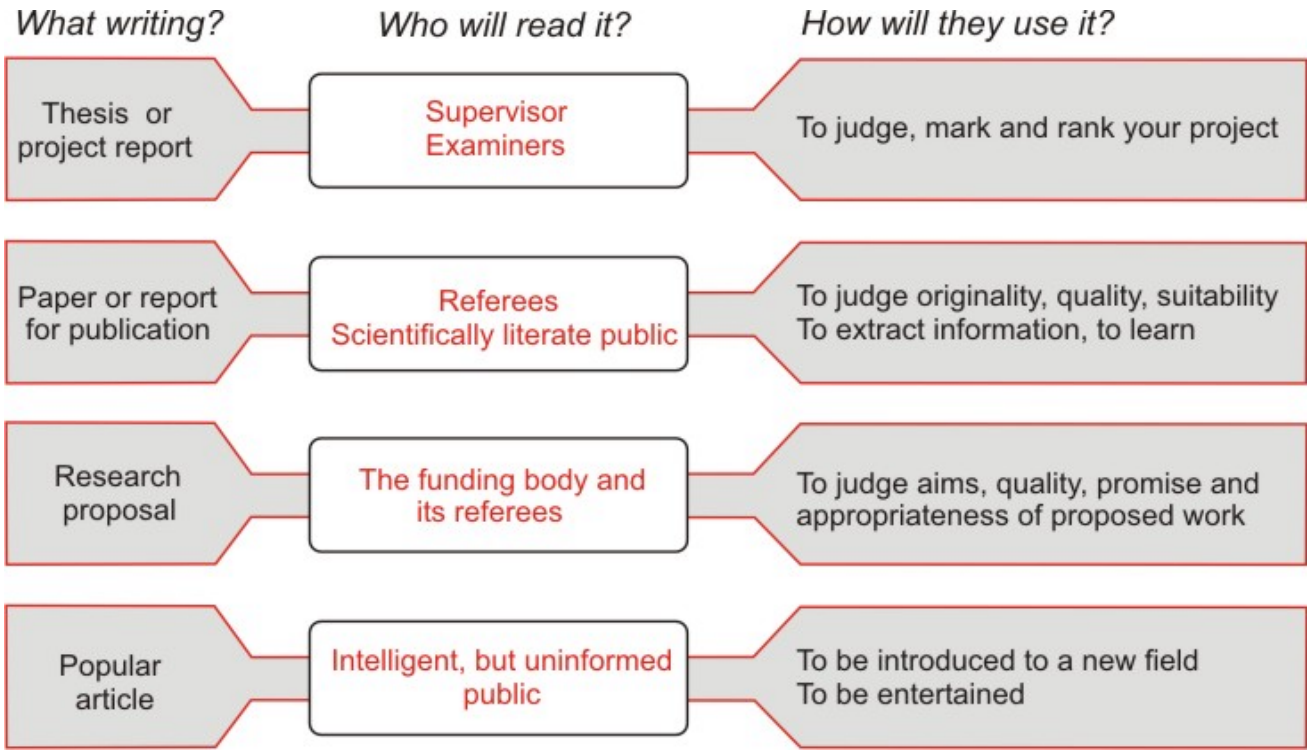


Figure 2. Markets for technical writing.

3 CONCEPT—Making a Concept-Sheet

When you can't write, it is because you don't know what you want to say. The first job is to structure your thinking. Settle down comfortably with a cup of coffee (or better, beer) and an A3 sheet

of paper in Landscape orientation as in Figure 3. Devise a tentative title for the paper and write it at the top. Then—in as orderly way as you can, but disorder is OK too—jot down what seem like sensible section headings, each in its own box. Sketch in anything that occurs to you that belongs in a section—paragraph headings, figures, ideas. Think of things that might be relevant to the section—a reference, a graph you might need, an idea that requires further development. Put each in a bubble near the box to which it applies, with an arrow showing where it fits in. This is the time to de-focus, forget the detail and think both longitudinally and laterally.

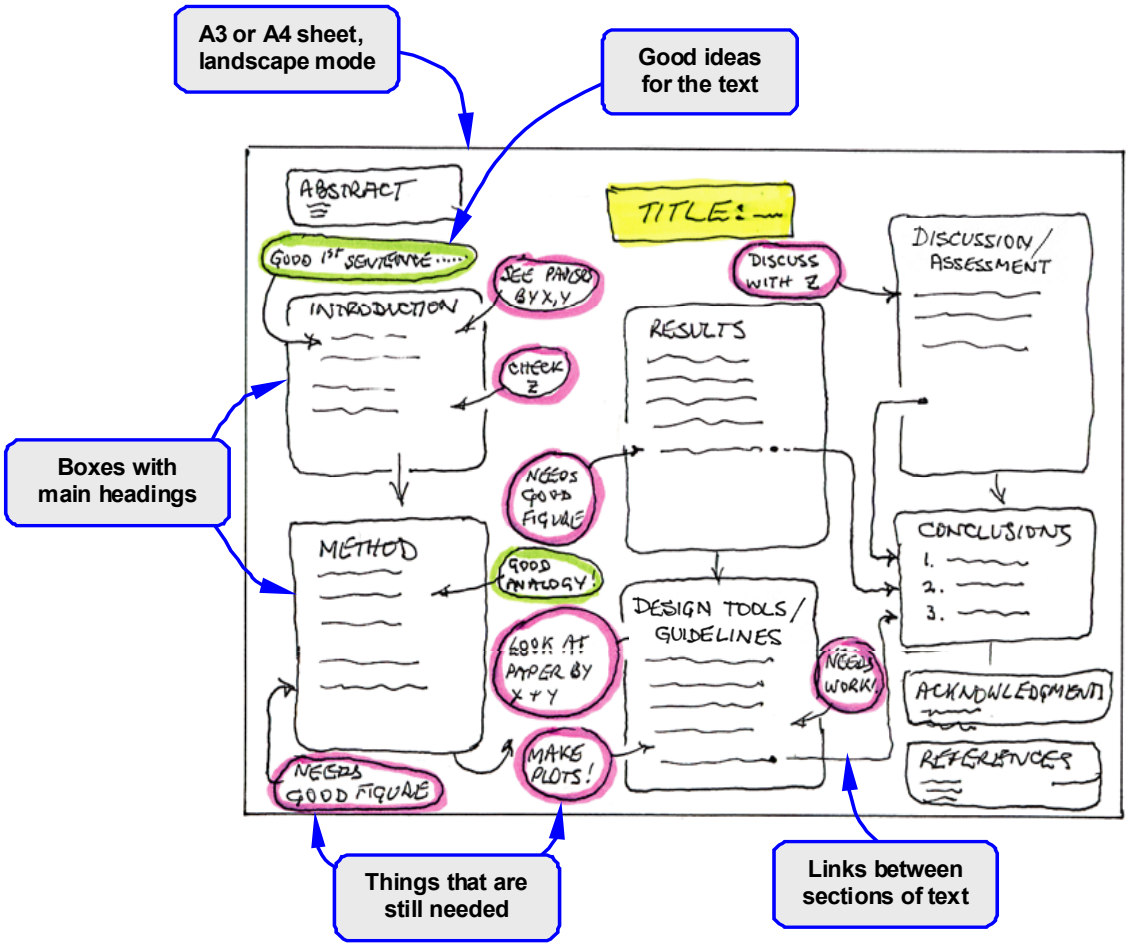


Figure 3. A model for a concept sheet.

What should be in the paper? What else might be relevant? What else might you need to do the job—a copy of X, a figure of Y, the reference Z? Put it all down. You realise that you need an extra section—squeeze it in. You see that the order of sections is not good—add arrows indicating the new order.

All this sounds like a child's game, but it is not. Its value lies in the freedom of thought it permits. Your first real act of composition (this one) is to allow your thinking to range over the entire paper, exploring ways in which the pieces might fit together, recording the resources you will need and capturing ideas. That way, no matter which part you start drafting, you have an idea of the whole. Don't yet think of style, neatness or anything else. Just add, at the appropriate place on the sheet, your thoughts. This can be the most satisfying step of writing a paper. Later steps can take time, be hard work, sometimes like squeezing water out of stone. But not this—it is the moment to be creative in whatever way your ideas may lead. You can add to the sheet at any time It becomes a road-map of where you are going.

Figure 4 shows, unexpurgated, the concept sheet I made while thinking about this manual. Some bits were already planned; most developed in the hour I spent making the sheet; a few were added later, after some sections had been drafted. It is a mess, notes to oneself, but it guides the subsequent, more tedious, part of the journey. It is possible that this starting point may not work for you, but try it more than once before you abandon it. It is the best way I know to break writers-block and launch the real writing of the paper.

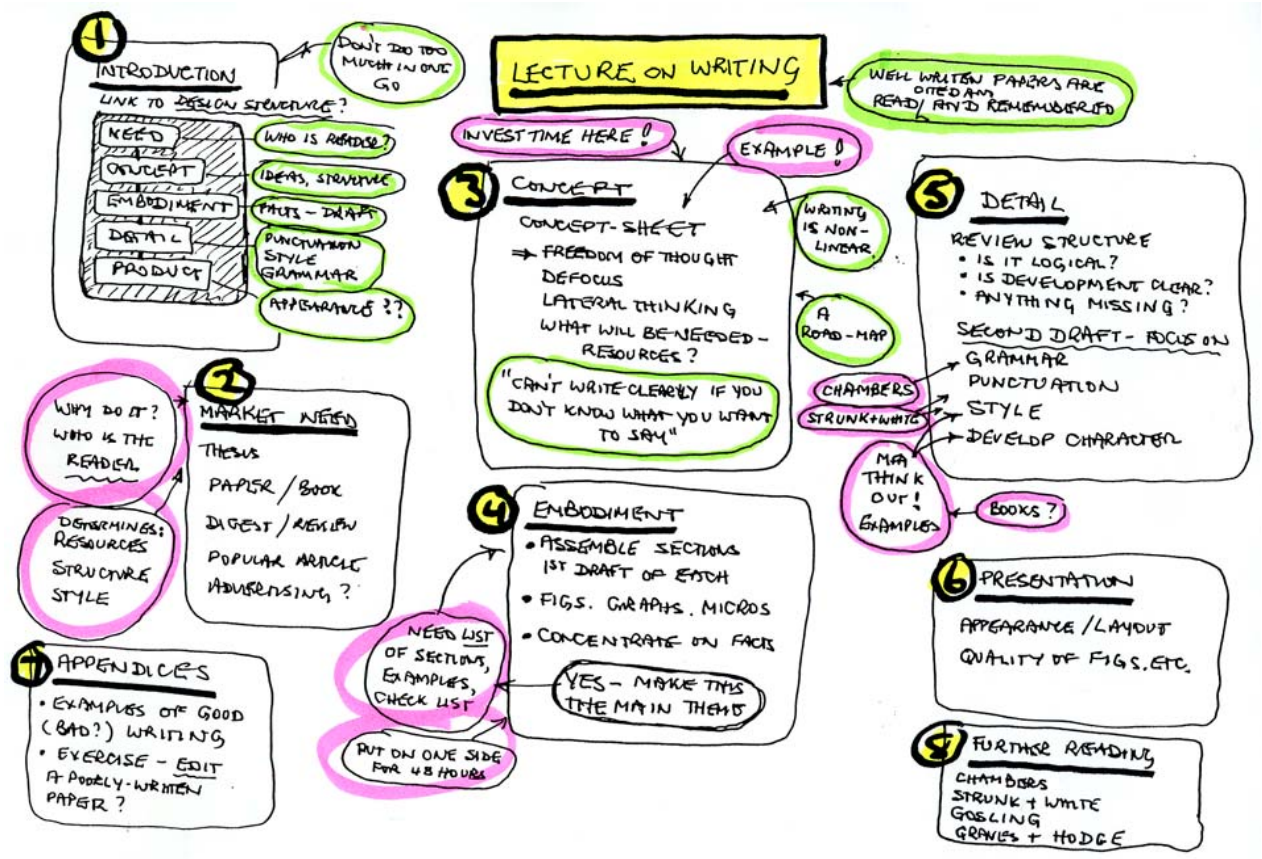


Figure 4. The concept sheet I made when writing this text.

4 EMBODIMENT—The First Draft

Now the hard work. Break the job down into stages. The usual stages in writing a paper are set out in the boxes below. Papers are not drafted sequentially; do it in any order you wish. Get the scientific facts and technical details down, the ideas formulated, the graphs and figures planned. If good ways of expressing the ideas occur to you now, use them; but do not deflect effort from the key job of assembling the pieces, in whatever form them come. Here they are.

4.1 TITLE

- **Meaningful and brief, in 14 pt bold.**

Fatigue of Metal Foams

is better than

The Mechanical Response of Cymat and Alporas Metallic Foams to Uni-axial Cyclic Loading

even though it is less specific.

4.2 ATTRIBUTION

- **The names of the authors, with all initials; the Institute or organisation, with full address; the date.**

"A.M.Harte and C.Chen,

The Cambridge Centre for Micromechanics,

Cambridge University Engineering Department,

Cambridge CB2 1PZ, UK

January 1999."

4.3 THE ABSTRACT

- **Try for one sentence each on *motive*, *method*, *key results*, *conclusions*.**
- **Don't exceed 3 sentences on any one.**

The reader of an Abstract has been lured by the title. He or she now want to know whether to read on. Tell them, in as few sentences as possible, what they will find. No waffle, no spurious details. Try not to exceed 100 words. Imagine that you are paying a 10p a word. See the Appendix for an example.

4.4 INTRODUCTION

- **What is the problem and why is it interesting?**
- **Who are the main contributors?**
- **What did they do?**
- **What novel thing will you reveal?**

Outline the problem and why it was worth tackling. Review the literature, recording briefly the main contributors and summarising the status of the field when you started the research. Provide any specialised information that the reader might need if he is to understand what follows. State what you will do that has not been done before (new experimental approach? new data? new model? new interpretation?) Keep it as brief as you can whilst still doing all this.

Start with a good first sentence—see Section 8 for examples.

4.5 METHOD

- ***Experimental paper:*** **equipment, materials, method**

  Modelling paper: **assumptions, mathematical tools, method**

  Computational paper: **inputs, computational tools, method**

- **Explain what is especially different about your method.**
- **Give sufficient detail that the reader can reproduce what you did.**
- **Don't mix Method with Results or Discussion—they come next.**

This should be an easy section to write: just say what you did, succinctly. Use "we" but do so sparingly: too many "we's" sounds like a child's day out: "first we did this, then we did that."

Build up a reference list as you go. See Section 4.10 for the way to deal with references.

It is one of the principles of science that a paper should contain sufficient detail to allow the work to be repeated by someone else. Provide this but no more. Keep the results for the next section.

4.6 RESULTS

- **Present the output of the experiments, model or computation.**
- **Don't mix Results with Discussion. It belongs—all of it—in 4.7.**

This, too, should be an easy section to write. Report your results simply, without opinion or interpretation at this stage. Define all symbols and units. Present data in a form other people can use. Give emphasis in the text the most important aspects of the tables, graphs or figures. Give error-bars or confidence-limits for numerical or graphical data. Statistics should be meaningful; avoid confidence-eroding statements such as "33.3% of the samples failed: 33.3% survived; the third sample was unfortunately misplaced."

Aim for a concise, economical style.

Poor: **It is clearly shown in Figure 3 that the shear loading had caused the cell-walls to suffer ductile fracture or possibly brittle failure.**

Better: **Shear loading fractures cell-walls (Figure 3).**

4.7 DISCUSSION

- **Extract principles, relationships, generalisations.**
- **Present analysis, model or theory.**
- **Show relationship between the results and analysis, model or theory.**

Here you are seeking to extract principles, relationships, or generalisations from the results. Sometimes the results speak for themselves.

The novel heat-treatment described in Section 2 gives steels which

are 10% stronger and 20% tougher than those heat-treated in the normal way.

could be all you need. Most of the research we do aims at *why* materials behave as they do, and this requires ideas about mechanisms, models and associated theory. The function of the Discussion is to describe the ideas, models and theories and lead the reader through a comparison of these with the experimental or computational data. Bring out the most significant conclusions first; develop subsidiary conclusions after that.

Be clear and concise; a Discussion is not a license to waffle. See Appendix for examples of waffle and what to do about it.

4.8 CONCLUSION

- **Draw together the most important results and their consequences.**
- **List any reservations or limitations.**

The reader scanning your paper will read the Abstract and the Conclusions, glance at the Figures and move on. Do not duplicate the Abstract as the Conclusions or *vice versa*. The Abstract is an overview of the entire paper. The Conclusions are a summing up of the advances in knowledge that have emerged from it. It is acceptable to present conclusions as a bullet-pointed list.

4.9 ACKNOWLEDGEMENTS

- **Thank people who have helped you with ideas, technical assistance, materials or finance.**

Keep it simple, give full names and affiliation, and don't get sentimental. A formula such as this works well:

I wish to thank Prof. L.M. Brown of the Cavendish Laboratory, Cambridge, for suggesting this review, and to acknowledge my debt to the books listed below.

or:

The authors wish to thank Professor A. G. Evans of Harvard University for suggesting the approach developed in section 4.3; Mr A. Heaver for his technical assistence throughout the project and Mrs Jo Ladbrooke for proof-reading the manuscript. The research was supported by the EPSRC under grant number EJA S67, by the DARPA-ONR MURI program under contract number N00014-1-96-1028, and by a Research Fellowship from the National Research Council of Canada.

4.10 REFERENCES

- **Cite significant previous work.**
- **Cite sources of theories, data, or anything else you have taken from elsewhere.**
- **References must be complete: name, initials, year, title, journal, volume, start-page and finish-page.**

References tell the reader where an idea, prior results and data have come from. It is important that you reference all such

sources. It is a conventional courtesy to reference the originators of key ideas or theories or models, even if you modify them.

There are almost as many different formats for references as there are journals. If you have ENDNOTE on your PC it can solve the problem. Best for drafts is the Name/year system (also called the Harvard system):

In text : "Lu (1998)". If there are two names then "Lu & Chen (1998)". If there are more than two, then "Lu et al (1998)".

In reference list, ordered alphabetically: "Lu, T.J and Chen, C. (1998*) An Analysis of Defects in Metal Foams*, Acta Mater. **15**, 222-226".

For papers: *Name, initials, year, title, journal, volume, start page-end page*.

For books: *Name, initials, year, title, publisher, city and country of publisher, chapter number, start page-end page* (if relevant).

All are important. Do not be tempted to make a reference list without all of these. It takes far longer to track down the missing information later than to do it right in the first place.

4.11 FIGURES

- **Flow charts show methods, procedures.**
- **Graphs plot data.**
- **Schematics show how equipment works, or illustrate a mechanism or model.**
- **Drawings and photographs illustrate equipment, microstructures etc.**

Anyone scanning your paper will look at the figures and their captions, even if they do not read the text. Make each figure as self-contained as possible, and give it both a title (on the figure itself) and an informative caption (below it). Make sure that the axes are properly labelled, that units are defined and that the figure will tolerate reduction is size without becoming illegible. Label each curve of graphs.

Good figures are reproduced or imitated by others, often without asking—the sincerest of compliments.

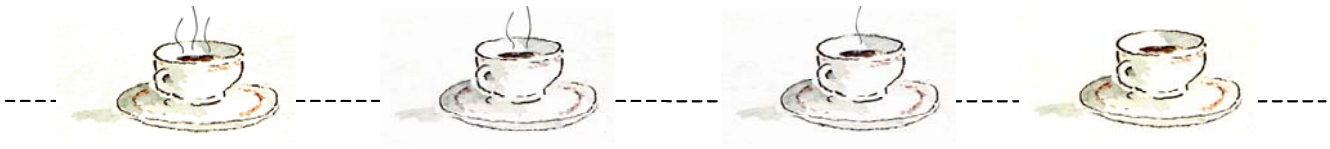
4.12 APPENDICES

- **Essential material that would interrupt the flow of the main text.**

An appendix must have purpose; it is not a bottom drawer for the stuff that you cannot bear to throw away. It is the place for tedious but essential derivations, or for data tables or descriptions of procedures, that would disrupt the flow of ideas in the main text. It should be well structured and stand by itself. Give it a title*: "Appendix A1: The Equation for Toughness"* The journal may set it in smaller type than the main text.

… … … …

When you get this far you have got a long way. Put the draft on one side for at least 48 hours. Get the graphs plotted, the figures drawn up, micrographs printed and references assembled. Do not tinker with the text yet. It is a good idea to have a check-list like the one on the last page of this manual; it helps you see where you are.



……Time has passed. The draft has matured for 48 hours or more. Now we must address the details.

5 DETAIL I: Grammar

Grammar tells the reader the function of words and their relationship. Mess up the grammar and you confuse the reader. What follows is a brief summary of the simplest essentials of grammar.

5.1 The parts of speech

Parts of speech are descriptors for the *functions* of words. There are eight.

- **Nouns** are the names of peoples or thing: *Instron, metal, computer, foam.*

Nouns can be used as adjectives. When so used, they are generally hyphenated to the noun they qualify: *table-tennis, metal-foam, computer-power*.

- **Pronouns** stand for nouns: *he, she, it, they.*

- **Adjectives** qualify nouns: a *small Instron, a red metal, a digital computer, an intricate foam.*

- **Verbs** signify being or action: *is, seems, go, interpret, understand.*

Transitive verbs have a subject and an object: *The load / deforms / the material.*

Intransitive verbs have no object: *Flowers / bloom. The research / evolved.*

"Being" verbs have a complement: *The test / was / completed. The theory / seemed / correct*. ("Completed" and "correct" are complements)

Many verbs have both a transitive and an intransitive form: *Time / passed.* And: *Pass the biscuits.*

- **Adverbs** qualify verbs: *today* we interpret this *differently.*
- **Conjunctions** link words and sentences: *and, but, because...*
- **Prepositions** precede nouns, usually having to do with place or time: *on* the table, *after* this procedure, *on* the graph, *from* the appendix.
- **Interjections** are exclamations; the polite ones include: *Alas! Great! Cheers!* Many are impolite. They are inappropriate in technical writing.

5.2 Sentence structure

A simple sentence has a subject and a predicate.

Subject	**Predicate**
The sample	***failed.***
The measurements	***fell into two classes.***
Fatigue-loading	***causes microstructural damage.***

The *subject* identifies what or whom the sentence is about.

The *predicate,* containing a verb, says something about the subject.

5.3 Phrases and clauses

Phrases and clauses are groups of words that do the jobs of the parts of speech listed on Section 5.1.

A *phrase* is a group of words that does not contain a verb.

Type of phrase	**Example**
Noun phrase	***The interpretation of the experiment presents a problem.***
Adjective phrase	***The red and white striped cable is live.***
Adverbial phrase	***We examined the results with considerable care.***
Conjunctive phrase	***The test ended owing to the fact that the specimen failed.***

Avoid the last of these; there is always a simpler, one-word conjunction (here: “because”).

A *clause* contains a verb and its subject or object. Sentences are made by linking clauses. A sentence made with two equal clauses (each a separate sentence but linked together) is called a compound sentence. A sentence made with a main clause linked to one or more subordinate clauses, which cannot stand by themselves as separate sentences, is called a complex sentence.

Adjective clauses do the work of adjectives; adverb clauses do the work of adverbs.

Type of Clause	Example
Adjective clause	**A computation *that uses FE methods* is appropriate.**
Adverb clause	**The modem will operate *wherever a phone-line is available*.**

5.4 Compound sentences

A compound sentence has two co-ordinate ("equal") clauses linked by a conjunction:

We measured the temperature and (we) adjusted the thermostat.

The tooling cost is high but the material cost is low.

The parts of a compound sentence must be of comparable weight. *"We analysed the microstructures using SEM and left for lunch at midday"* is unbalanced.

5.5 Complex sentences

A complex sentence has a main clause and a subordinate clause:

What these results signify / is the subject of a paper by Wegst (1998).

Maine (1998) demonstrates / that technical cost modelling is feasible.

It is possible / that the conclusions were mistaken.

5.6 “that” and “which”

“The computations *that were performed on a Cray* were the more accurate.”

“The computations, *which were performed on a Cray*, were the more accurate.”

These two sentences appear at first sight to say the same thing, but they do not. The italicised part of the first sentence is an adjective clause, qualifying the word “computations”; it has the effect of limiting the computations the sentence is talking about to the ones done on the a Cray, as distinct (say) from those done on a Silicon Graphics work station. Adjective clauses are just like adjectives; they are not separated from the noun they qualify by commas.

The italicised part of the second sentence, separated by commas from the rest, adds a new factor of equal importance to that contained in the main sentence. The two statements are: the computations were performed on a Cray; and they were more accurate. The emphases of the two sentences differ. The italicised clause in the first sentence is *subordinate*, merely qualifying the noun. The italicised clause in the second sentence is *co-ordinate*, meaning that it introduces a new fact.

6 DETAIL II: Spelling

Use the spell-checker on your computer, but remember that it will fail to distinguish “their” from “there”, “form” from “from”, “its” from “it’s”, and many more. Watch out particularly for “effect” and “affect”, “principle” and “principal”, “dependent” and “dependant”, “compliment” and “complement”.

Most word ending in “-ise” can also be spelt “-ize”, but not all. If, like me, spelling is one of your lesser talents, use “-ise”.

And when in doubt, use a dictionary.

7 DETAIL III: Punctuation

Punctuation orders prose and sends signals to the reader about how to interpret it. Good sentence structure and punctuation makes reading flow; it warns of what is to come; it helps the reader read without having to re-read. Meaning is changed, sometimes dramatically, by punctuation. It is one of the toolboxes of good writing. The next three pages give a resume, but if you really want the low-down on punctuation, and to be entertained at the same time read “Eats, Shoots and Leaves” by Lynne Truss, listed under “Further Reading” at the end of this manual.

7.1 The full stop, or period .

The full stop is used to mark the end of a declarative sentence, and to signify abbreviation: *Dr. A. M. K. Esawi, Ph.D.*

7.2 The comma ,

The comma keeps apart two words or larger parts of a sentence which would confuse if they touched. Forget any rules you have heard about the comma and simply used it when it improves the sense of the sentence. Try the sentence with and without the comma; keep it if, without it, the sentence becomes ambiguous. Thus:

The measurements employed a photo-diode and a laser was used to

check adjustment *requires a comma after* photo-diode *to avoid a momentary misinterpretation, slowing the reader down.*

7.3 The semi-colon ;

The semi-colon is used to separate when the comma is not enough and the full stop is a more complete break than the sense demands. Most commonly, it is used between closely related independent clauses:

At one time the optical microscope was the principal tool of metallography; today, it is the scanning electron microscope.

When conjunctive adverbs *accordingly, also, hence, likewise, similarly*… link clauses, they are proceeded by a semi-colon. It is used, too, to separate members of a list when the comma is not enough:

The literature includes Gibson (1997), who studied simple compression; Olurin (1998), who studied the effect of holes and notches; Deshpande (1999), who….

7.4 The colon :

The colon introduces part of a sentence that exemplifies, restates or explains the preceding parts. It is expectant: it sets the reader up to anticipate elaboration.

This raises the question: is the model right or wrong?

There are two reasons for repeating this experiment: the first, to improve the precision; the second, to establish reproducibility.

7.5 The exclamation mark !

The exclamation mark signals surprise, excitement, imperative, even contradiction; it turns up the volume.

Harte reports that metal foams sink in water.

is a simple statement;

Harte reports that metal foams sink in water!

implies that this is startling, perhaps even mistaken. Scientific writing does not need this sort of emphasis or innuendo. Delete it, and say what you want to say in a direct way.

7.6 The question mark ?

The question mark is used after a direct question:

Why was this work undertaken? The reason…….

It is used to indicate uncertainty: **Euclid, 450? —374 BC.**

It is optional after a rhetorical question:

Who would trust that model.

So what.

7.7 The hyphen -

The hyphen connects part of a compound word:

Well-known; half-expected; curiosity-provoking; a ball-and-stick model.

It is generally required when a noun is used as an adjective: *a box-*

girder; *a bar-chart*. Its most engaging property is its capacity to create new words and meanings by combinations both established and original:

A Fleck-inspired interpretation; a shark-skin-textured surface.

But treat this with caution; it can easily descend into stomach-lurching purple-prosed absurdity.

7.8 The dash —

The dash sets off parenthetic material that results in a break in continuity in a sentence.

Magnetic materials—carbon steels for instance—contain atoms with unpaired electron spins."

This conclusion—and it is a significant one—appears to violate the first law of thermodynamics.

The remaining specimens—those which had not fractured—were sent for analysis.

A dash can lead to an upshot, a final summary word or statement, and give emphasis:

Cell-wall bending, cell-wall buckling and cell-wall fracture—are all equally probable.

7.9 The quotation mark “ ”

Quotation marks enclose direct “word-for-word” quotations and dialogue.

“Uncork the flagon; let the wine-cups flow.”—Horace, Odes, 27BC.

“One small step for a man; one giant leap for mankind.”—Neil Armstrong, US astronaut (1969).

Quotation marks are sometimes used to enclose an original, ironic or unusual turn-of-phrase*:*

This research took a “try-it-and-see approach.”

This colloquial phraseology is uncomfortable in scientific writing; avoid it.

7.10 The apostrophe ’

The apostrophe shows either possession or contraction; thus, the possessive forms: *Sutcliffe’s theory; everyone’s idea.*

There is no apostrophe in the possessive *his, her* or particularly, *its*.

In contractions, the apostrophe indicates missing letters: *Don’t, isn’t, it’s* (meaning “it is”). Contractions of this sort are inappropriate in scientific writing, but can be acceptable in informal or popular writing, as here.

7.11 Italics *italics*

Underline, embolden or italicise? All three attach emphasis and importance to a word or phrase. In contemporary scientific writing

italics are preferred. Bold tends to be reserved for headings. Underlining can appear over-emphatic and, within a text, bold can seem authoritarian. Italics allow smooth definitions of terms:

"The critical value of the fatigue limit, or *fatigue threshold,* is listed…"

allows the italicised words to be used thereafter in place of the longer definition. Book titles are often italicised "*The Theory of Shell Structures"* by C.R.Calladine, as are words in foreign languages. To write more on this would be *de trop.*

7.12 Parentheses ( )

Parentheses—literally: putting-asides—embrace material of all sorts, and help structure scientific writing. But do not let them take over, clouding the meaning of the sentence with too many asides.

Face-centred cubic metals (copper, silver, and gold, for instance) have nine independent elastic constants.

Shercliff (1998) surveys the status of modeling in Material Sciences .

It is plausible (although not everyone agrees) that this theory is correct.

7.13 Brackets [ ]

Brackets are used to indicate editorial comments or words inserted as explanation: *[continued on p. 62], [see footnote].*

8 DETAIL IV: Style

A good style lifts writing from that which is dull and ordinary to that which is distinguished, memorable, individual. There is no formula for instant style—it is partly a personal thing—but there are useful guidelines. Style is approached through plainness, simplicity, good structure and desire to convey information to the reader in the most accessible way.

8.1 Be clear

The essence of technical writing is *communication*. The first quality, with precedence over all others, is clarity. Use simple language and simple, concise construction; short words rather than long; familiar words, not obscure. When you've said something, make sure that you've really said it. The writers of these headlines (all from newspapers in 1998) hadn't:

Red tape holds up new bridge.

Something went wrong in jet crash, expert says.

Chef throws heart in to help feed the hungry.

Prostitutes appeal to Pope.

Panda mating fails; vet takes over.

These are funny because the intended meaning can be guessed. More often, it can't; then the loss of clarity misleads and confuses.

AND DON'T WAFFLE. Consider this, from a well-known Materials text:

"The selection of the proper material is a key step in the design

process because it is the crucial decision that links computer calculations and the lines on an engineering drawing with a real or working design".

What does it say? "Materials selection is important", and we knew that already. It is wasting the reader's time.

8.2 Write from an appropriate design

Poor writing lacks order, mixes ideas that should develop separately, fails to progress in a logical sequence. The concept-sheet gives structure: there is a place on it for each part of your story. In making it, decide where the bits will go, the logical order, the way they will fit together.

Remember who you are writing for. Tell them what they want to know, not what they know already or do not want to know.

8.3 Define everything

Define all symbols and abbreviations.

The mass m scales as E/ρ where E is Youngs's modulus and ρ is the density… leaving a double space on either side of a symbol when it appears in the text.

The measurements, made with a scanning electron microscope (SEM), …

allows you to use the abbreviation SEM thereafter.

8.4 Avoid empty words

Avoid clichés (standard formalised phrases): they are corpses devoid of the vitality which makes meaning spring from the page:

The long and the short of it is that digital methods are the flavour of the month; the bottom line is that analog computation is old hat—

avoid it like the plague.

Avoid weak qualifiers: ***very, rather, somewhat, quite…***

This very important point … makes less impact than: ***This important point*** … or, more simply: ***This point*** ….

The agreement with theory is quite good suggests that it is not.

These ideas could rather easily be extended to the non-linear case … makes the reader wonder why you didn't do it.

8.5 Revise and rewrite

Revising is part of writing. Nobody gets it right first time; some go through 8 or 10 drafts. The most spontaneous-seeming prose is, often, the most rewritten. Do not be afraid to write the first draft with the simple aim of getting all the facts down on paper. You can then see what you've got, and can extract, revise, and distil a paper, a conference report or a research proposal from it, as needed.

8.6 Do not overstate, over emphasise or apologise

All of these undermine the reader's confidence in your judgment.

This paper questions the basic assumptions of fracture mechanics **…**(this from a real manuscript) fills the reader with mistrust; after all, fracture mechanics works.

This very important result…., This significant finding…. are better replaced by the simpler ***This result…*** and ***This finding….***

Leave the reader to decide on importance and significance.

And never, ever, apologise.

Unfortunately, there was insufficient time to complete the last set of tests

suggests bad planning, laziness, incompetence.

8.7 Avoid being patronising, condescending or eccentric

Write in a way that draws attention to the sense and substance or the writing, not to the mood or whimsical humour of the author. If the writing is solid and good, the character of the author will emerge. To achieve style, start by trying for none.

Don't patronise: ***The amazingly perceptive comment by Fleck …..***

Don't be condescending: ***Readers familiar with my work will know …..***

Do not affect a breezy manner, what you might call Web-speak.

Hi! me again with some hot news about engineering at CUED, or Q'Ed as we call it. It's been a helluva term for good stuff—we got more going on here than ever before…The author says nothing and is showing off, drawing attention to himself.

8.8 Use appropriate language

Use standard symbols and terms. Calling Young's modulus G will confuse, even after you've defined it.

Minimise the use of acronyms and abbreviations.

The MEM, analysed by FE methods, was photographed by SEM and chemically characterised by SAM.

is bad writing. Find other ways of saying it, even if it takes more words.

Avoid jargon. Jargon is the secret language of the field. It excludes the intelligent, otherwise well-informed, reader, and speaks only to the initiated. Some jargon is unavoidable—new concepts sometimes need new words. But don't be tempted to use it to show that you are an insider. The Appendix has examples.

And above all, remember who you are writing for.

8.9 Good first sentence

Don't start introductions (or anything else) with platitudes. Tell the reader something he does not already know. Openings such as:

It is widely accepted that X (your topic) is important …

has the reader yawning before you've started. Try to get a new fact, new idea or a revealing comparison into the first line.

Poor Opening: Metal foams are a new class of material attracting interest world-wide and with great potential… X, Y, Z have

measured their strength properties …P, Q, and R have developed theoretical models … Comparison of the experiments with the models suggests that the measured strength are less than those predicted …

The first sentences is a platitude; the second and third involve the reader in details, the relevance of which is not yet clear; only in the fourth does the point start to emerge.

Better: Metal foams are not as strong as they should be. Models, which describe polymer foams well, overestimate the strength of metal foams by factor of 2 to 5. This research explores the reasons.

***To be more specific*… (details of literature X, Y, Z, P, Q, R here).**

The first two sentences now highlight the problem. The third says what the paper is going to do. The details that follow then have relevance.

Use a quotation only if it is spot-on; inappropriate quotations give the impression that the writer is trying too hard.

"God created solids, but the Devil created surfaces"—anon.

could be a good first line for a review-article on friction and wear, but it is pretentious as an opening to a paper on (say) the wear of bronze journal bearings. If you do use a quotation, make sure you get it right —see Quotations, in Further Reading.

8.10 Seek helpful examples and analogies

Ferro-magnetic material—steels, for example—can be shock-loaded

by pulsed magnetic fields.

The example of steels makes the generalisation concrete.

One cause of rolling friction is material damping. A rolling ball deforms the surface on which it rolls. If the work done in this deformation is lost through damping, a frictional force opposes motion. It is like riding a bicycle through sand: the rubbing sand particles dissipate energy much as atom or molecular rearrangements do.

The bicycle analogy is appropriate; it relates the scientific problem to one which is familiar.

There are more examples of analogies in the Appendix.

8.11 Linking sentences

Each sentence in a paragraph should lead logically to the next. When you read a paragraph, where does it jar? Why did you have to pause or re-read? What word-change will fix it? Edit for readability.

It helps the reader if one paragraph ends with a device that links it to the next: a word or phrase picked up in the first sentence of the following paragraph, or a statement of what is coming next (though be sparing with this, it can get tedious).

……To progress further, we need a way to rank the materials—a material index.

A material index is a ……

The repeated words link the two paragraphs.

……..This behaviour suggests that the process is diffusion-controlled. A model based on this idea is developed next.

The stresses at grain boundaries can be relaxed by diffusion. …

The reader knows what the second paragraph is about before reading it.

8.12 Observe good writing

When you read a good opening, an apt analogy, an illuminating example, or an idea well expressed, re-read it. Don't try to imitate it directly, but observe how the author did it. Bit by bit you can absorb the techniques.

8.13 Finally…

Style takes its final shape from an attitude of mind, not from principles of composition. Focus on clarity. Make sure you've said what you think you've said. And remember who your readers are; seek to express your results and ideas in ways they will most easily grasp.

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9 FURTHER READING

There are lots of books on how to write, spell, punctuate. Many are deadly dull. But there are some good ones, some *really* good ones—not just instructive, inspirational almost, and entertaining too. I've starred them (★) in the list below.

Texts on how to write technical prose

"The Complete Plain Words" 3rd edition, by E. Gower, revised by Greenboum, S. and Whitcut, J. Penguin Books, London, UK (1986)

"A Writers Guide for Engineers and Scientists" By R. R. Rathbone & J.B. Stone, Prendice-Hall Inc, Englewood Cliffs, NJ, USA (1962)

★ "The Reader Over Your Shoulder" By R. Graves & A. Hodge, Collier Books, New York, USA (1943).

"The Elements Of Style" By W.Strunck Jr., & E.B White, Macmillan Co, New York, USA (1959).

"Communication in Science", 2nd edition, by Vernon Booth, Cambridge University Press, Cambridge UK (1993).

"The Little Brown Handbook", 6th edition, by H.R.Fowler and J.E. Aaron, Harper Collins, New York, (1995)

Instructions on preparing scientific papers

"General notes on the Preparation of Scientific Papers", 3rd edition, (1974), The Royal Society, London.

Grammar

"Clear English' by Vivian Summers", Penguin Books, London, UK (1991)

"Chambers English Grammar" by A. J. Taylor, W & R Chambers Ltd (1990)

Punctuation

★ "Eats, Shoots and Leaves" by Lynne Truss, Profile Books, London, UK (2003)

"The Well-Tempered Sentence" By K.E Gordon, Horton Mifflin Co Boston, USA (1993)

Spelling—the friendliest dictionary is

The Chambers Dictionary, Chambers Harrop Publishers, London U.K. (1998)

…….but the ultimate authorities remain

The Concise Oxford Dictionary, 8th edition, Clarendon Press, Oxford UK (1990), or

The Shorter Oxford English Dictionary, 4th edition, Clarendon Press, Oxford UK (1990)

Quotations

The Oxford Dictionary of Quotations, 4th edition, Oxford University Press, Oxford U.K. (1996)

Synonyms and Antonyms *(words that say the same or the opposite)*

The Penguin Dictionary English Synonyms and Antonyms, Penguin Books, London, UK (1992).

If words fascinate you, the following are delightful:

★ "Troublesome Words" 2nd edition, by Bill Bryson, Penguin Books, London, UK (1987).

★ "Panati's Extraordinary Origins of Everyday Things" by C. Panati, Harper and Row, New York, USA (1987).

★ "Panati's Extraordinary Endings of Practically Everything and Everybody" by C. Panati, Harper and Row, New York, USA (1989)

★ "Dictionary of Word Origins" By J.T. Shipley, Littlefield, Adams & Co, NJ, USA (1977).

★ "Word Histories and Mysteries" Edited By K.Ellis, Horton Mifflin Co Boston, USA (1974).

★ "The Penguin Dictionary of Curious and Interesting Words'" By G.S. Sausy III, Penguin Books, UK And Viking Books USA (1984).

APPENDIX: Some examples of effective and ineffective writing

Good Abstract

Temography of Shear Bands in Metal Foams

Metal foams, when compressed, deform by shear banding; the bands broaden as deformation progresses. We have studied the nucleation and broadening of shear bands by laser-speckle strain-mapping. The foams were non-homogeneous, with spatial variations of density of a factor of 2; the shear bands nucleate in the low-density zones, and broaden into the high-density regions as strain progresses. The results indicate that processing to minimise the density fluctuations could increase the initial compressive yield strength of the foams, when shear bands first form, by a factor of 1.5.

This, in four sentences and 94 words, gives a clear, concise portrait of the paper, devoid of unnecessary detail and secondary information.

Good opening sentence

From a review article on the elastic properties of materials

"Ut tensio, sic vis". As it is stretched, so it resists. With these words

Robert Hooke enunciated in 1674 the law of elasticity that bears his name

Enzio Manzini, in "The Materials of Invention", Design Council, London 1989.

The quotation nicely suggests the history and introduces the subject.

Good analogy (1)

Structured Programming

'Music, poetry, and programming, all three as symbolic constructs of the human brain, are found to be naturally structured into hierarchies which have many different nested levels. Sounds form meaningful units, which in turn form words; words group into phrases, which group into sentences; sentences make paragraphs and these are organised into higher levels of meaning. Notes form musical phrases, which form themes, counterpoints, harmonies etc; which form movements, which form concertos symphonies and so on.

Structure in programs is equally hierarchical, if not so universally recognised…'

'Numerical Recipes' by Press, H W. Flannery, B.P. Teukolsky, S.A. and Vetterling W.T. Cambridge University Press, Cambridge, UK (1986).

The analogy is a little long-winded, but it achieves the writers' aims: to convey the importance of structure in programming, and , by association, to portray programming as an art-form and to elevate its stature as an intellectual activity.

Good analogy (2)

The Character of a Volvo

'Volvos have a certain character. Purchasers see them as solid, safe, long-lasting, reliably masculine, with built-in Scandinavian qualities of good design — it's what we call the "Product DNA" …..'

Ford Company spokesman explaining that Ford, who have just bought Volvo, will retain and develop the Volvo character.

The DNA analogy captures in a word the subtle combination of real and perceived values which lie at the heart of customer loyalty.

Avoid Waffle

The Role of the Materials Engineer in Design

'The role of the Materials Engineer in the design and manufacture of today's highly sophisticated products is varied, complex, exciting and always changing. Because it is not always the metallurgical or materials engineer who specifies the materials, this *ASM Handbook*

on Materials Selection and Design is prepared to benefit all engineers who are involved with selecting materials with their related processes that lead to a ready to assemble manufactured component.'

Extract from the Introduction to ASM Metals Handbook vol. 20, ASM International (1998) Metals Park, Ohio, USA

There is a warning here for us all. What they wanted to say is: "Engineers need to choose materials and to find processes to shape and join them. This ASM Handbook is designed to help them."

But that sounds too short, too plain, not grand enough. The fear of sounding trivial, of not being sufficiently heavyweight, haunts all writers when they are asked to write for audiences with whom they are unfamiliar. The temptation is to use long words, to sound sophisticated, to get fancy; and the effect is to dilute the message until its true flavour is lost. I have been just as guilty of it as anyone else. Don't do it. Say what you mean to say and say it clearly and simply.

Remember who your readers are.

The Act of Design

'**Designing is a creative activity that calls for a sound grounding in mathematics, physics, chemistry, mechanics, thermodynamics, hydrodynamics, electro-engineering, production engineering, materials technology and design theory, together with practical knowledge and experience in specialist fields. Initiative, resolution, economic insight, tenacity, optimism, sociability and teamwork are**

qualities that will stand designers in good stead and are indispensable to those in responsible positions.'

From a distinguished book on Engineering Design

How many people do you know who could meet that job description? The authors wish to convey the idea that design is an inter-disciplinary activity, and one that has technical, managerial, and social facets, but they have done so in a way that intimidates. They have lost touch with their readers. An alternative with the same message might be:

Designers cannot be expected to know everything, yet there are times when it might seem that they must. Design involves an exceptionally broad base of technical competence and practical experience, leadership, teamwork and management skills.

Try not to alienate your readers. Phrase your message with them in mind.

Jargon (1)

A Definition of love

'… the cognitive-affective state characterised by intrusive and obsessive fantasising concerning reciprocity of amorant feelings by the object of the amorance.'

At a US Conference of Sociologists (1977), cited by Bryson (1987)—see Further Reading

This sort of stuff is rife in critiques of music and art, and in writing on Psychiatry, Psychology and Sociology. It surfaces, too, in books on Industrial Design, and, less frequently, in scientific and technical writing. Don't let the jargon-bug infect your own style.

Jargon (2)

The justification for a travel grant

My mathematical work is in the area of Symplectic Geometry and Differential Equations, in particular on a geometrical interpretation of the Painlevé equations. I have succeeded in attacking the Isomonodromical Deformation problem for higher order singularities by symplectic means. On the one hand, this involves a symplectic structure obtained from infinite-dimensional considerations and on the other an analysis of the geometry of the Stokes matrices in the language of Poisson Lie groups.

From a students application for a travel grant (1999)

There's nothing wrong with the grammar, punctuation or spelling here —all are fine. But how much does the statement convey to the panel awarding the travel grant, all of them scientists or engineers, but none specialists in this sort of mathematics? Practically nothing. The meaning is hidden in the jargon; the writer has made no attempt to translate his ideas into a language the rest of the world can understand. It is not always easy to do so—the subject of Symplectic Geometry may be a difficult one to illustrate with simple examples or analogies—but it is always worth trying.

CHECKLIST FOR MONITORING PROGRESS

Make concept sheet	☐

	1st draft	edited draft
Title and attribution	☐	☐
Abstract	☐	☐
Introduction	☐	☐
Method	☐	☐
Discussion	☐	☐
Conclusions	☐	☐
Acknowledgements	☐	☐
References	☐	☐
Figures and captions	☐	☐
Appendices	☐	☐

Visual presentation	☐