The K-Zone: How to write a technical report

Kevin Boone, Principal Instructor, Sun Microsystems UK

Version 1.03, January 2003

Summary
This article gives some general guidelines on writing a technical or scientific report. It describes the `standard model' of report writing, and some alternatives. The article is intended for students who are currently undertaking undergraduate or master's degree projects, or expect to do so in the near future.

Contents

1 Introduction
The ability to write clear, concise reports is an asset to almost any professional. In this article I offer some general guidelines on report writing, focusing particularly on something I call the `standard model'. This `standard model' is a formalisation of the way that scientific reports have usually been written over the last fifty years or so. While the standard model has its detractors, and is often used inappropriately, it still has a lot to recommend it. I normally suggest to students who don't have much writing experience that they follow this model unless they have good reasons not to. In this article I will also try to explain *why* we recommend that reports are written in a particular way.

2 Fundamentals
The main purpose of a technical report is to convey information. The report should place as few hindrances as possible between the mind of the writer and the mind of the reader. A secondary function is to stimulate and entertain. There are people -- a tiny minority -- who can inform and entertain at the same time. If, like most people, you have to make a choice between the two, you should try to inform rather than to entertain. Of course, if you were writing a novel the priorities would be reversed; but in report writing it is the information that is paramount.

   A good report needs careful planning. As part of the planning stage you should try to answer the following questions.

- What is the report *about*? What are you trying to say? You should arrange things so that they key facts and conclusions are very accessible. Not everyone will read the whole report, so ensure that your message will get across even if a person only skims the document. I have been told -- and tend to believe -- that senior managers have an attention span of about four minutes. This suggests that if you are writing with these people as your audience, your report should start with a summary that can be read in a few minutes. In fact, this is a good idea whatever the audience.

- Who are you writing for? It is simply impossible to write a technical document that will be equally easy for everybody to read: the level of explanation you need for an expert audience is totally different from that needed for readers who are unfamiliar with the subject. It is absolutely essential that you identify the potential readers -- the professional

group, not the individuals -- before you start work. In the university environment your report will probably be read by lecturers. These people will have a good knowledge of their subject in general, but will probably not know much about the precise field of your report. You should always bear this in mind. If you are writing for computer scientists you don't need to explain, for example, what a modem is, nor the World-Wide Web, but you *will* need to explain what phase modulation is, and what `CGI' stands for.

- How long can the report be? It's difficult to predict in advance exactly how long a report will be, but you should be able to decide whether you will be writing 2,000 words or 20,000 words. It's generally harder to write a short report than a long one, because it requires much better organisation. In the university environment there may be official limitations on the size of the report.

3 The standard model

The `standard model' of report writing is a style and structure that has been widely used in the western world for about 50 years. It is the reporting method that is usually taught in schools. Contrary to what we are taught in schools, however, it is *not* the only accepted way to write in science. Nevertheless, it is the way that most professional scientists and engineers choose to write. The main features of a report that follows the `standard model' are as follows.

- The first major section is an introduction; the last is a conclusion. The conclusion answers questions posed -- explicitly or otherwise -- in the introduction.

- Factual material and measurements are kept completely separate from opinion and interpretation, often in different chapters or sections.

- Formal, and rather impersonal, language is used.

- The report usually refers quite extensively to the work of other individuals.

- The sections of the report are numbered.

Most `standard model' reports will contain some or all of the following sections, *usually in this order*. Each of these sections will be discussed in more detail below.

- `Abstract' or `summary'.

- `Acknowledgements'.

- `Introduction'.

- `Objectives'.

- `Theory'.

- `Method' or `methodology' or `procedures'.

- `Results'.

- `Discussion' or `interpretation'.

- `Conclusion'.

- `Recommendations'.

- `References' and/or `bibliography'.

- `Appendices'.

A `standard model' report will probably also contain a table of contents, a list of abbreviations and technical terms, and perhaps an index if the document is long.

3.1 Abstract or summary
An abstract or summary (they mean essentially the same thing) should contain a brief overview of the report, including its conclusions and recommendations if there are any. A good length for an abstract is 300 words; some scientific journals actually specify this number of words explicitly. The abstract of a scientific paper or report is considered to be capable of `standing alone' and being published separately. For this reason the heading `abstract' in a report is usually not numbered. Numbering usually starts with the introduction.

3.2 Introduction
The introduction sets out what the report is about, and what its role is in relation to other work in the field. If describing experiments, the introduction will usually summarise other related experiments, and show how the work to be described extends or supersedes these earlier studies. If the report is about development (e.g., software development) the introduction will often set out what the purpose of the development is, who will benefit, and how it will be used. If the report is a review, it will usually just state the scope of the report and the readership for which it is intended.

In most technical reports, the introduction will say something about the context of the report, that is, how the work it describes forms part of the overall body of work in that subject area. When describing an investigation, the introduction will usually state explicitly what the investigators set out to find.

My approach is to finish the introduction with a list of the questions I set out to answer, and give the answers to these questions in the conclusions. I like to be quite explicit about this, and even label the questions `question 1', `question 2', etc. Whether you do this or not, the reader should be able to look at the conclusion of your report and verify that you have found out what you claimed you would find out.

3.3 Objectives
This section, if present, states what the work being reported was expected to achieve, why it was undertaken, and at whose instigation. I usually prefer to put this information at the end of the introduction, but this is just a matter of taste.

3.4 Acknowledgements
It is polite to give a brief note of thanks to those people who have helped *directly* in the work the report describes. In a novel, the authors often thank their friends and family; most scientists and engineers consider it slightly pretentious to do this in a technical report. In the last few weeks I have read technical reports that acknowledged the invaluable assistance of the late Princess of Wales, Jesus, and the author's pet dog. I would like to know in particular the role played by the dog.

If the report is destined for publication, and describes work supported by a grant, the grant-awarding body may insist that it be acknowledged. It seems reasonable to me to do this.

3.5 Theory
The theory section, if used, describes any background theory needed for the reader to understand the report. Such a section is usually found only in reports that use mathematics that the typical reader cannot be expected to know in advance.

3.6 Method
In the `method' section you should describe the way the work was carried out, what equipment you used, and any particular problems that had to be overcome. If the report is describing a survey, you should say how you chose your subjects, how you checked for bias, and how you analysed the results.

3.7 Results
In the standard model, results are usually given as plainly as possible, and without any comment. It is often difficult to know how much data to put into this section. My feeling is that you should include enough data to enable to reader to be confident that you have done what you said you would do, and that your conclusions will be trustworthy. This certainly does not mean

that you should include reams of print-outs and copies of questionnaire returns. I try to summarise the results into a few tables and graphs.

Most readers that are used to reading scientific reports will become uncomfortable if you call a section `results' and put anything in it apart from plain results.

3.8 Discussion

In this section the author provides an interpretation of the results, compares them with other published findings -- if there are any -- and points out any potential shortcomings in the work.

The `discussion' section of a traditional report is the place where the author is allowed to be less objective than usual. In this section it is acceptable to mention opinions, and speculate slightly about the significance of the work.

In particular, if your findings are unusual, or very much at odds with other people's conclusions, you should explain why you think this might be. Otherwise the reader will probably assume you have just made a mistake.

3.9 Conclusion

The conclusion gives the overall findings of the study. It is important to realise that `conclusion' does *not* just mean `the last bit of the report'. Your conclusions should really be statements that can be concluded from the rest of the work. A conclusion is not a summary. (You can include a summary as well, if you like). When I mark students' reports, one of the questions I ask about them is `do the conclusions follow from the body of the report?'

3.10 Recommendations

In this section the author normally includes any advice he or she wishes to offer the reader. If the report is about making some sort of business decision, the appropriate course of action will usually be recommended here. Some people use the recommendations sections for suggestions of further work, which seems reasonable to me.

3.11 References and bibliography

The purpose of citing references is to allow the reader to follow up your work, and perhaps check that the conclusions you draw really follow from the sources you cite. References are not, as many students appear to think, a method for convincing the examiner that you have read a lot. You should give enough detail that if the reader wanted to follow up your references, he or she would be able to do so. For books, you should give the authors, year, edition (if there's more than one), publisher's name and publisher's location. For articles in journals give the authors, year, name of the publication, volume and page numbers. If you can't give all these details, you probably don't have a proper reference.

The rise in Web-based publishing has created its own citation problems. The same basic principle applies, however, as it does to citing printed works: the citation must be sufficient to allow the reader to follow up the reference. If possible, you should cite a URL that will take the reader directly to the document you cite. Giving the URL for a `home' or `welcome' page is generally not helpful. As a matter of good style, you should give the names of the authors and the publication date, if you are able to determine them.

Although it is not peculiar to Web-based publication, authors should be aware of the problem that not all references have equal weight. References to articles in peer-reviewed journals will be more convincing than references to non-reviewed sources. Since anyone can publish anything on a Web site, there is a real risk of citing something that is not very authoratitive.

Many students seem not to know the difference between `references' and `bibliography'. The bibliography is the set of publications that the authors referred to *in a general sense* in writing the report or carrying out the work it describes. These publications will not usually be cited explicitly in the text. References, on the other hand, are given in support of some specific assertion, and are always mentioned explicitly in the text. Normally this citation would be given after the statement the author wants to support. A common method is to give the authors and year in the text, e.g, (Bloggs, 1995), and the full details at the end of the report or in a footnote.

In scientific writing, if you make any statement that is not one of plain fact or measurement, you *must* justify it, or refer the reader to another publication where it is justified. The making of unjustified assertions is probably the single most common criticism leveled at students' writing.

If you use another person's words directly, you *must* be clear about this and give a full reference. If you use more than a few words, or a picture, or results, you should seek the author's permission first, and state in your report that you obtained

such permission. If you don't do this you're probably breaking the law, as well as being unprofessional.

3.12 Appendices
The appendices are where the author will usually place any material that is not directly relevant to the report, and will only be read by small number of people. I usually use appendices for mathematical proofs, electrical circuit diagrams and sections of computer programs.

3.13 Numbering and structure
It is common to number each section of the report. Usually numbering starts at the introduction, which has number `1', and continues until the references. Because they are in a sense independent of the body of the report, the abstract and references are not usually numbered. Most people number sub-sections as well. So, for example, in section one, sub-section two would be numbered `1.2'. Other people prefer to use numbers and letters, e.g., 1A, 1B... This is fine as well. The advantage of using a hierarchical numbering scheme like this is that it helps to orient the reader. It allows the most important section divisions to be identified at a glance.

3.14 When should you use the standard model?
In my opinion, writers of technical reports should use the standard model, or something close to it, unless there is a sound reason not to. Why? First, and most important, its use is so widespread that the reader will know exactly what to expect in each section. Moreover, if the reader needs to refer to your report quickly he or she will know immediately which section to turn to. Second, it is well `signposted'; even people who are not familiar with this type of report will find the clear section divisions useful in their understanding. Third, the rigid organisation of the report will help the novice writer organise his or her thoughts when writing.

There are times when the standard model will be a hindrance, rather than a help. In these cases you should cheerfully abandon it and adopt something else. In particular, you don't need to include all the sections. A `results' section, for example, is only useful if you are reporting results or measurements.

4 Alternatives to the standard model
Here are a few suggestions of other ways to organise a technical report.

4.1 The `segmented' standard model
If a report describes a set of investigations with a common purpose, but different methodologies, it can be rather difficult to use the standard model, even if each individual investigation could be reported that way. In this case it is quite useful to give each experiment its own `segment', with a `method' and `results' section, but use single overall `introduction' and `discussion' sections. In the `segments', one does not necessarily need to use explicit sub-sections for method and results, as long as the reader is clear where the boundaries are.

4.2 The `assertion' model
This is quite unusual in a report (it is widely used in presentations and posters) but in some circumstances it can be very effective. In this type of report, rather than using very passive section titles like `Introduction', the author uses very active, direct statements, like `the new protocol improves communications efficiency by 23%'. The headings together make up a summary of the report. Of course, if you make an assertion you then have to go on to defend it. The great advantage of this type of presentation is that the reader can get an overall idea of what the report says simply by reading the headings at the top of each section.

4.3 The `conclusion first' model
In this type of report, the conclusions are presented towards the beginning, perhaps directly after the introduction. In my opinion one should re-state or summarise the conclusions at the end as well, otherwise the report ends abruptly. The advantage of placing the conclusion at the beginning is that it is more likely to be read. It also allows the reader to have the conclusions in mind while reading the rest of the report. I don't use this method myself; I prefer to put a short summary of the conclusions in the abstract.

4.4 The `topic' model

In this type of report, each section of the report is on a particular topic or subject, but there will probably be a common introduction and conclusion. This structure is appropriate for review or instructional articles, but is probably not very useful for scientific reports. The problem here is that it does not lend itself to the division between methodology, results and interpretation that most readers will expect.

5 Language, style and presentation

If your message is one of profound importance, it will be communicated rapidly even if presented badly. On the whole, however, few scientific and technical reports contain ground-breaking findings. In this case the author must pay more attention to issues of communication to encourage people to read the report.

5.1 Grammar and spelling

Most academics and scientists, and many businesspeople, are relatively fussy about grammar and spelling. This is probably because such people read a great deal, and have learned to extract as much information from a document as possible in a limited time. This is only possible if everyone follows very similar standards of grammar and spelling. Whatever the reason, the only way the author can be sure that no reader is likely to be alienated by inadequate grammar and spelling is to ensure that they are impeccable.

If your grammar and spelling are not particularly good, it is vital that you have your work read by someone else before you decide that it's finished (I think that everyone should do this anyway). At the very least you should get a printed copy of your document (not on a computer screen) and check it very thoroughly yourself.

5.2 Style

Most technical documents are written in a rather formal style. Some readers get upset when they have to read reports that are written informally, but I don't mind this. However, what does annoy me as a reader is sudden changes from formal to informal writing. For example, if the author adopts a impersonal, formal style (using phrases like `at this point the operator should click on the button labelled ``start"...') and suddenly switches to an informal, personal form (`now you should click on ``start"...'), it can be very confusing.

In the UK, technical writing is usually dominated by `passive voice' expressions, where the author tries to avoid using the word `I'. Personally, I am inclined to use the word `I' whenever I think it is appropriate to do so. If you prefer not to, that's fine. However, you should avoid writing very ugly phrases just to avoid the word `I'. For example, a phrase commonly used in scientific articles is `It is the opinion of the author that...' This means *exactly* the same as `I think...' but has four times as many words. Lawyers tend to write `It is submitted that...' which is even worse. Submitted by *whom* exactly? Another error is to use the word `we' when `I' is correct. For example, to say `we sent questionnaires to 500 middle managers' is incorrect if it was just the author that did this (of course it is correct if there was more than one person involved). The worst affront to the language of this type is the *double passive*. An example I saw recently was this: `It is regretted that transparencies are not able to be accepted'. What the author meant was: `Sorry, we don't accept transparencies'. Authors must make up their own minds about the good points and bad points of these different styles, but should do so after careful consideration, rather than according to dogma.

The use of passive-voice expressions has probably derived from authors' attempts to give the impression of impartiality when reporting scientific findings. I don't think anyone will be fooled into thinking than if you sound impartial, you are impartial. But that's just my opinion.

In general, I think appropriate humour is fine in a technical report. The problem is this: if your report is about, say, theorem proving methods, what sort of humour is likely to be appropriate? Many attempted jokes detract badly from the message the author wants to convey. Nevertheless, occasionally it works.

On the whole you should probably not write the way you speak, for two reasons. First, you probably use colloquial and ungrammatical expressions in your speech that the reader will not understand (I'm sure I do). The reader cannot stop you and ask for an explanation. Second, in writing you don't have access to the differences in emphasis and tone of voice that help spoken communication. As you have to rely entirely on the words themselves, you need to choose them with some care. My favourite example of an inappropriate colloquialism occurred in the discussion section of a report I read on Web-based learing. In doubting the validity of some statement or other, it said ``there's a great big question mark hanging over this". In speech this would have been fine, because the speaker's tone of voice would have indicated that he did not intend the

statement to be taken literally. In the report however, where everything else was written in a formal way, it immediately brought to mind an image of a flying question mark.

5.3 Presentation

Good presentation is, I venture to suggest, less important than sound technical content. However, that does not mean that it is unimportant: the decision about how much time a potential reader is prepared to spend looking at your report will be based to a large extent on the first impression made by the presentation.

With modern computer software, it is relatively easy to prepare well-presented documents. One area that such software does not offer much help with is that of *consistency*. A document is consistent if, for example, it always uses the same typeface for headings and for captions, if all lines have the same spacing, if all pictures are centred on the page, and so on. The simple solution to this problem is to print the document and have it looked at by an impartial, critical person.

The final part of report preparation is usually binding. It doesn't cost very much to have a report spiral-bound, and it will be much easier to read than if it is stapled or ring-bound. Hot glue binding can be very effective (and cheap) for thin documents. Unless there are rules to the contrary, it is probably not worth the effort and expense of hard binding a report. I like to receive reports that are glue-bound in plastic covers so I can read them in the bath without getting wet fingerprints on the pages.

6 Visual material

Very few technical reports consists only of text; it is usual to include graphs, photographs, or charts as well. Here are a few hints on including such material; these should all be quite obvious, but sometimes people forget.

- Label everything. All charts and graphs should have a caption and perhaps a number (`figure 1'). Check that when you refer to figures in the text, these references are correct. It commonly happens that people add or remove figures, then forget to update all the cross-references.

- If you prepare graphs in colour, then print them on a monochrome printer, they may become unreadable. For example, it will not be possible to distinguish between a line that was originally back and one that was blue. Some computer software automatically converts graphs to use dotted and dashed lines on a printer, but most does not.

- Photographs do not usually photocopy very well. You may need to get extra prints made of photographs so that you can include prints with each copy of the report.

- Unlike in an advertising or promotional brochure, colour presentation is not usually worth the extra effort in a technical document (except in certain subjects, like computer graphics and multimedia). Many scientific journals do not print in colour, or will only do so if given a financial incentive. It's worth checking this before starting work on the report.

- Computer software that is designed for producing slide presentations will often not use sensible type sizes when used for producing diagrams for printing on paper. A good size for text labels on a diagram is 12-14 points.

7 Things to avoid

Here, in no particular order, are some suggestions of things to avoid in a technical report. Note that I am not saying they should be avoided in all types of writing; but a technical report has a particular function and audience, and the writing should reflect this. Naturally this section describes things that *I* particularly dislike; it does not necessarily follow that everyone else will feel the same.

- Avoid clichés and stock phrases. *Clichés* are phrases that were probably witty and stylish when introduced, but their very appeal has made them so over-used that they are likely to annoy the reader. Remember that the readers of technical reports probably read *a lot*. They will be quite likely to have seen the same cliché used several times that day. Here are some particularly common examples: `at the end of the day...', `explore every avenue', `not to put too fine a point on it...', `going foward, we will...'
  Stock phrases are slightly different from clichés; they are phrases that writers in a particular discipline tend to use

too often, not because they read well, but because they get used to reading them. Particular examples include `at this point in time...', `in the opinion of the author...' The problem with these phrases is that often they add nothing at all the the content, or could be replaced by a single word. For example `at this point in time...' can usefully be replaced by `now...'

Some people use stock phrases because they don't have anything else to say; if you don't have anything to say, it's better not to say anything.

- Avoid giving too much data. I suspect that some people include too much data for the same reason that some people employ useless stock phrases: because they don't have much to say. I favour including only a summary of experimental data in a report.

- Avoid poems and other non-technical material. This sort of thing is inoffensive when it relates to the subject of the report, but very annoying if it does not.

- Avoid computer program listings and long mathematical proofs. It is unlikely that anyone will want to read them, and anyone who does want to can ask you for a copy later.

- It is probably a bad idea to include statements about how difficult the work was, and how the report would have been better had the author had more time. Students often say this sort of thing in reports, and it doesn't look very professional.

8 General guidelines

Finally, here are a few general suggestions, in no particular order.

- Decide what you want to say, then say it. It is very difficult to think about what conclusions to draw from your investigation, for example, at the same time as writing these conclusions. When you come to write a report, you should be in a position to think only about reporting, not about investigation or data interpretation.

- Before you write very much, check whether there are standards you are required to conform to. As a student you may find that your place of study has quite detailed rules about report presentation. At PhD level it almost certainly will. Some institutions specify exactly which typefaces to use for various levels of heading, and so on. For journal publication, you'll probably find that you have to provide either `camera-ready' copy, or plain text with separate figures. `Camera-ready' means that you should provide the finished material, ready to go to the printer. You'll have to do all the formatting and layout yourself, according to the journal's rules. For most journals, however, you'll be expected to provide plain text -- no layout or formatting -- and the figures on separate pages. I mention this because there's no point spending time on getting the flow of text around your figures exactly right, when you'll end up putting them on separate pages.

- You don't have to write the report in the same order you expect it to be read. Very often the introduction is the hardest thing to write, as you need to summarise all the work and your conclusions very thoroughly. A lot of writers start by writing ``1. Introduction'' and then spend a few hours staring at a blank page (or blank screen). In this case you would be better writing part of the report that is more straightforward. Often those parts of the report that deal with methodology and procedures are quite easy to write, as no interpretation is involved.

- A shorter report is a better report. If you can say the same in 2000 words as in 5000, then it's better to write 2000 words. Most people, including myself, write too much at first. By this I mean that, having written something, I can readily remove about 20% of the words with no loss of meaning. Be ruthless: edit your work thoroughly after writing.

- People find it hard to be critical of their own work. I suggest that you regard everything you write as a draft, until it has been read by at least one other person. That other person need not be an expert in the subject, in fact it is often better if you choose someone who is not an expert.

- Make all important style and authorship decisions before you start. Decide in advance, for example, the degree of balance between formality and informality you will use in writing, whether you will adopt the passive or active forms, and so on. Having made these decisions, stick to them. If you change your mind, make sure you change the whole report. Many readers become quite uncomfortable if these major stylistic decisions change in the middle of a document.

- It's usually better not to edit your document *at all* until you have written the whole thing, at least to first-draft standard. It's very easy to get bogged down with the details of individual sentences, and then find later that you need to remove whole sections. If this happens, you will find that writing a report takes much longer than it should.

- Writing good reports is difficult, and usually takes longer than the author anticipates. If possible, allow yourself twice as much time as you first think you'll need.

Bibliography

There are many good books on the subject of technical writing, but, in my opinion, none of these are written by or for computer scientists. The following books are the ones to which I referred when I started writing. Although they don't deal in particular with computing, the guidance on planning, layout and style is relevant to most subjects.

- Burchfield RW (1996) *Fowler's modern English usage* 3rd edition (Oxford: Oxford University Press)

- King LS (1978) *Why not say it clearly?* (Boston: Little, Brown and Company)

- O'Connor M (1991) *Writing successfully in science* (London: Chapman Hall)

Of these, O'Connor (1991) is probably the most accessible for beginners, but the style it advocates is a bit stuffy for my taste. I can't be sure than any of these books (apart from *Fowler's*) are still in print, but in any case you should look for a book that suits your own preference.