Guide to Prospectuses and Other Technical Writing

Dean Wheeler
2018

This brief guide is provided to aid my graduate students in writing the M.S. or Ph.D. prospectus required by the BYU Chemical Engineering Department. It supplements the information contained in the department's Graduate Student Handbook. Many of the principles here also apply to writing scientific papers, reports, and the thesis or dissertation.

1 Objectives and audience

For any kind of writing you should understand the objectives of the document and tailor your material for the intended audience. The objectives for almost all technical writing are to

- Sell your ideas. This means you should convince the intended audience that your experiments and theories are important, interesting, valid, and useful.
- Disseminate scientific knowledge. This means you should accurately and concisely document your experimental procedures, mathematical model, and numerical results for others to use and verify.

The prospectus is a *research proposal.* It is written to gain approval to carry out the project. In defining the scope of your project, the approved prospectus becomes a kind of contract between you and your committee so that you know when you are done. It is recognized that you may change directions along the way, but with the prospectus in hand you have a place to start and an idea where to stop.

Because the prospectus is written before most of the research work is done, the emphasis is on the first item above ("Sell your ideas"). You must convince your graduate committee that

- Your project addresses an important problem in an appropriate way.
- You have adequate preparation and a plan to solve the problem in a reasonable amount of time.

The audience is your graduate committee, a small group of professors. They will understand general chemical engineering concepts like process optimization, phase and chemical equilibria, kinetic vs. transport limitations, validation of numerical models, experimental design, and data analysis. Not all committee members are experts in your particular subfield, and so will need to be given the appropriate background material to understand the terminology and theory specific to your project. They need to be told what is "common knowledge" in your subfield and what is new and innovative about your work.

2 Content

Below is the general order of topics that I recommend, along with a suggested length for each item for a Ph.D. prospectus. The Ph.D. prospectus should contain about 24 total pages (not including bibliography); an M.S. prospectus should contain about 10 total pages (not including bibliography).

1. Give a brief background of your field of work, identify a problem, and establish the problem's importance (around 1 page). This is your opportunity to generate interest in the audience about your project. Avoid using highly technical jargon at this point.

2. State the scope of your project (half page). Do not just say you will work on X or study subject Y. Instead give scientific hypotheses you will test or research questions you intend to answer, and outline the tools and methods you will use.

3. Outline the topics that are covered in the remainder of the document, i.e. give a road map (small paragraph).

   Note: it is vital that the introduction (items 1 through 3) be well polished in order to generate a good first impression and set the tone for the remainder of the document.

4. Do a more extensive background discussion on the problem, showing you have a good grasp of the field in which you are working (around 10 pages). This section includes your "literature review," though don't name it as such. In particular, describe where others' prior work overlaps with your proposed work, showing ideas you can gain from them or knowledge gaps that need to be filled. You are preparing your audience to understand the nature of the problem and appreciate the value of your proposed solution in item 6. Extensive experimental details or equations are not appropriate in a research-proposal type of document.

5. Give prior results generated by you, showing a few quantitative or theoretical results to demonstrate you know how to get started and have been able to overcome a couple early hurdles (2 pages). You do not need to show everything you have done—the purpose is to establish your credibility in carrying out the proposed research, not to provide the same level of detail that would be found in an academic publication. Sometimes this section can be combined with item 4 or item 6, depending on the best logical flow of material.

6. List the tasks that are required to answer your hypotheses or questions, giving detail on the technical challenges you anticipate and how you plan to overcome those challenges (around 8 pages). While doing this, provide the logical framework guiding your choice of tasks, so that the reader can see why the proposed activities are the best means of answering your questions. Figures and tables illustrating the proposed experimental design(s) are quite helpful. Give alternative paths (backup plan) if your original plan of attack is not successful. State how you will maintain laboratory safety.

Note: items 4 and 6 will each require multiple subsections as you cover different technical topics. Also, help the committee to distinguish your unique contribution to the field by explicitly identifying ideas that are new to your work as opposed to ideas that originated with others.

7. Give a time line or Gantt chart summarizing the tasks and steps that will lead to completion of dissertation or thesis (half page), including the specific papers you plan to write and publish.

8. List cited references in a section at the end (2 or more pages). Use a consistent citation format taken from a leading journal in your field.

3 Wheeler's points of style

Below are my advice and "rules" for improving your technical writing. They are often based on my observations of trouble spots for beginning technical writers.

General scientific writing

1. Good writers habitually reread and rewrite what they have written, to fix mistakes and make improvements. They take ownership of their work and pride in producing a high-quality product. The best writing requires many edits and drafts over the course of days and weeks.

2. Printing out a draft of your document can be helpful in detecting mistakes, because the text and formatting will appear differently to your eye than on a computer screen. Try it and see.

3. When someone else edits your document, learn from their edits so you do not repeat the same mistakes. The editor may be your advisor or simply a "fresh pair of eyes," a person who doesn't necessarily need a technical background. There is a temptation to postpone fixing grammar and spelling mistakes until the end. However, with a polished draft your advisor can spend more time addressing "big picture" things like the logical structure and flow of ideas, rather than getting distracted by the grammar and spelling mistakes.

4. Good writers tune their writing to their audience's general level of technical experience and prior knowledge and interest in the topic, which will be different from the writer's current knowledge and interest. Try to *anticipate* a typical reader's questions and objections, gaps in knowledge, and what they will find confusing or tedious. Then modify your writing to meet those needs and expectations. Similarly, follow the golden rule in writing: write the kind of paper that you like to read. Think about particular papers that have been especially helpful to you as a beginning graduate student. What did the authors do that was so helpful? Then write that kind of paper.

5. Scientific writing is essentially telling a *story* built from logical thought, decisions, and data outcomes. In the initial stages of writing, outline or sketch the series of figures and tables that will contain the data that tell your story. Further, to convince your audience that your work is sound, you must do more than tell them *what* you did; you must also tell them *why* you made the scientific choices you made: Why this type of experiment? Why this particular model? Why these assumptions? Take the reader through the logical process that you followed.

6. Make sure the *introduction* is particularly interesting, effective, and organized. It sets reader expectations for the remainder of the document. A person should never have to read more than one or two pages of the introduction before finding out the main ideas and scope of your work.

7. The *abstract* is a fully independent summary of the document, and so has parallel purposes to the introduction in securing reader interest, though in a shorter format. The abstract additionally contains an overview of the principle methods, findings, and results of the work.

8. Use headings or subheadings *at least* every two pages. Transitions between major sections are a good time to remind the reader where you are going. This kind of road map helps the reader track the logical progression of topics.

9. Every time you write a paragraph or section, ask yourself: "What is the *single main idea* of this paragraph or section?" That idea should come out in the first one or two sentences. Do not switch ideas in the middle of the paragraph or section; instead start a new paragraph or section. Do not include extraneous information that does not support the main idea. If I were to read only the first sentence of every paragraph in your document, I should get nearly all the important ideas, if not the details.

10. You cannot presume an audience will simply trust your conjectures or opinions. Whenever you present an idea or conclusion that is not generally understood or accepted in the scientific community, or is likely to be questioned by your audience, you must *support it* by mathematics, logic, or data or provide a citation that does the same. If the matter is not central to your project, a citation is generally preferred. If you cannot support a questionable statement, then you should qualify or narrow the statement so that it is supportable, or eliminate it entirely.

11. You must provide a citation for any unique ideas, text (even if you change a few words around), images, or data you obtain from another source. While it is less common in scientific writing (paraphrasing is often used), if you directly use the words of another, they must be enclosed in quote marks or otherwise set apart. Not to give credit by citation is called plagiarism, and this academic sin can have serious consequences.

12. Copyright is a different concept than plagiarism (though the two concepts can overlap). Copyright law requires that you get permission from the copyright holder before using a significant portion of another's work in your own. For instance, if you want to reproduce a figure from a scientific paper in your own document, you must contact the publisher of the journal for permission to do this, which permission they generally give.

Scientific grammar

1. Technical writing requires a precise choice of words to convey meaning clearly and concisely. With each sentence, ask yourself: "Is there any way for a reader to misinterpret the meaning of this sentence?" As one example, confusion can arise if you use an anaphor (e.g. *it* or *this* or *that*) to refer to an antecedent (a previous idea, object, or person) and it is not clear to which thing or things you are referring because there are multiple possibilities. Also, make your lists complete: avoid use of "etc." in lists because it requires logical extrapolation and the meaning may therefore be unclear.

2. Compound adjectives abound in technical writing. A compound adjective is a group of words that operate together to modify a noun. Such often require hyphens to eliminate possible misunderstanding. As an example of the importance of hyphens in compound adjectives, note the difference in meaning in the following phrases: man eating dog vs. man-eating dog, twenty two minute delays vs. twenty two-minute delays, out of the box solution vs. out-of-the-box solution.

3. When discussing upcoming sections, figures, and equations in the present document, or discussing enduring scientific principles, use verbs in the *present* tense. Example: "Section 2 describes prior experimental results" or "kinetic energy is given by the following formula." When discussing human actions, such as experimental data collection or the work of others, you may use the appropriate *past* or *future* tense.

4. The first time an acronym is used, it must be defined by using parentheses, e.g. "focused ion beam (FIB)." If your reader at some later point is likely to have forgotten an acronym (particularly for long documents), then define it again as a courtesy. Do not use inappropriate capitalization in your definition: "Focused Ion Beam (FIB)" is wrong.

5. Some academics insist that personal pronouns and possessives (*e.g. I, we*, *my*, *our*) not be used in technical writing. This is an old tradition that is losing its hold. As appropriate you may occasionally use personal pronouns in describing your proposed research and results, in order to avoid awkward passive constructions. On the other hand, do not overdo the use of personal pronouns: the science, not the people doing the science, should be the main focus of the writing.

6. The choice of article (the/a/[none]) on a noun depends on whether it has been introduced yet and is familiar to your audience as a specific instance. In other words, you could initially say, "this work requires *a* new type of conductivity experiment." After this experiment has then been properly described you refer to it as "*the* conductivity experiment."

7. Whether to use *a* or *an* as the indefinite article depends on how something sounds when spoken aloud (*an* FBI agent, not *a* FBI agent).

Figures and Tables

1. Tables are used for data sets where the reader clearly will want to obtain precise and accurate values for their own use from your results. Otherwise figures are preferred because of the brain's ability to rapidly assimilate information and detect trends when data is presented graphically. Avoid putting the same set of data in both tabular and graphical form.

2. Each table and figure should be numbered, and have a caption that contains a title and, in most cases, an additional description that allows it to "stand on its own" without other supporting text (even so, each table and figure should also be referenced and discussed in the main body text). Table captions go above the table; figure captions go below the figure. Multi-part figures have a single caption that describes the parts in sequence (a, b, c, etc.). The caption should define any symbols or lines in the plot or special conventions in presenting the data.

3. Generally speaking, in your plots represent experimental data with points or symbols; represent fits to the data or theoretical relationships with lines or curves. If you use a series of graphs to represent related data, use a consistent system of symbols and colors to aid the reader. If you use Microsoft Excel to generate plots, know that the default settings do not make for nice graphs in printed documents—you will need to adjust formatting so it looks better.

4. If you are describing an important experimental apparatus or model geometry that is unfamiliar to your audience, a line drawing or schematic is necessary.

5. When possible, use appropriate file formats for figures: *vector* format for line drawings and graphs (.eps, .svg, .wmf) and *raster* format for photos and images (.jpg, .tif, .png, .gif). When using raster formats, make sure that dpi (dots per inch) is at least 300.

Equations

1. Whenever an equation is given, all variables should be defined if they have not been defined previously. For some journals an equation should be punctuated with a comma or period as part of a sentence.

2. An important equation should occupy its own line and be numbered. Example: the ideal gas law is

$$PV = nRT\,, \tag{1}$$

where P is absolute pressure, V is volume, n is number of moles, R is the universal gas constant, and T is absolute temperature. Make sure to use the same equation editor when defining variables in the text as is used for the full equation, so that they appear with the same font.

3. Do not format your equations how they would look in computer code. Make sure that parentheses, brackets, and braces are sized and nested appropriately. Compare the two ways of formatting the following equation:

$$(\int((n-1)/(n+1)+n^3)dn)^2$$

vs.

$$\left[\int\left(\frac{n-1}{n+1}+n^3\right)dn\right]^2\,. \tag{2}$$

4. A less important or smaller equation can be given as part of a line of text (so-called in-line equation) and must be formated so that it is not too tall or the font too small. For instance, the expression $\dfrac{N^2}{3}$ could be better formatted as $\frac{1}{3}N^2$ or $N^2/3$.

5. Format quantities appropriately: $h = .221$ is wrong, $h = 0.221\,\mathrm{W/(m^2K)}$ is right; $k = 1.2E-3\frac{W}{mK}$ is wrong, $k = 1.2\cdot 10^{-3}\,\mathrm{W/(m\cdot K)}$ is right. Make sure there is a "hard" or non-breaking space (ctrl+space) between the number and its corresponding unit—this prevents them from being placed on different lines of text.

6. All variables should be italicized with the following noted exceptions. Greek-letter variables and named dimensionless numbers (Re, Pr, Nu, etc.) should not be italicized. Vectors and matrix variables should be in bold font, unless one is referring to an element: v_i is scalar element i of vector $\mathbf{v}$. Chemical formulas, units, and common mathematical functions should not be italicized. Descriptive subscripts and superscripts that contain multiple letters that form a word or an abbreviation should not be italicized (e.g. k_i^{eff}, $x_{a,b}^{\mathrm{max}}$, t_{avg}). With the exception of particular dimensionless numbers, avoid using primary variable names with multiple letters (e.g. C_V is better than CV).