How do I write a good first draft of a report or a paper for Dr. K?

I. Introduction

This document outlines the set of rules and guidelines for writing good quality reports and papers for Dr. K. Having corrected same types of mistakes repeatedly for many students, I decided to put this document together to help my students avoid making the same mistakes. Therefore, please check your draft against this document's rules and guidelines, and make sure that whatever in this document that applies to your document is satisfied fully before you give me a copy of your draft. Check against this document and revise your draft at least twice before giving me a copy for review. Read this document carefully before you write the first draft.

Note that this document started with M.S. reports in mind, but over time, it turned into a document that collects writing tips, rules, and guidelines for papers as well as reports. Hence, I use paper/report interchangeably. What applies to your paper/report should be clear from context. If you are not sure, attempt to follow the rules. If you are not still sure, please see me.

II. Paper/Report Outline

A typical outline of a report is not much different from a well-written journal article or a conference paper. You can use a paper that you like and that does *similar work* as a model for your outline, for general presentation ideas, for anything that you can think of or for anything you have difficulty on putting in written form. *Similar work* usually means that the paper has some parallels with your own work: Computational or theoretical, optimization-based or heuristics, modeling focused or methodology focused. Good writers usually follow a different outline and presentation style, and focus on different details, depending on the work.

However, a high-level outline like the following is usually a good start:

1. Introduction and motivation
    a. General problem statement (what are you doing?),
    b. Motivation (why are you doing your work and why is it important? A simple illustrative example could be used if it makes this easier),
    c. Your contribution (what do you do in your research, brief but rigorous and exact, and what is different from others' work?),
    d. Brief outline of the rest of the report.
2. Literature review
    a. Review others' work (Categorize others' work, follow a chronological/categorical flow, focus on the development of findings and differences/contributions of the papers, rather than citing just what they actually do)
    b. Position your paper in the light of others'
3. Problem Statement

    a. A detailed problem statement (Explanation of notation, mathematical model, and its properties if necessary)
4. Solution Methodology(ies) and Analysis
    a. Give the main idea(s) of the approach
5. Computational Study
    a. Experimental Design
    b. Computational Results
6. Conclusions and Future Research
    a. Summarize what you have done, focus on what you learned that you didn't know before the study (your contribution)
    b. Identify and summarize future research directions (put some rather obvious extensions (short-term) and some long-term directions, potentially to be done by others)
7. References
    a. List of all the papers you cite in the main text of the report. Use alphabetical order.
8. Appendices

III. General comments

1. **The most important item:** Make sure that everything that you have in your report/paper is yours. Do not even directly copy one sentence from anywhere else (paper, book, web site, etc.) without adapting to your context, your style, and your flow of information, and without filtering from your own view of the problem or the approach. If you have to take any part without changing/adapting it, use quotation marks. Give proper credit to the source, whether you use quotes or not. Cheating (knowingly or unknowingly) could be in one of many forms, each with the same bad result. If you are not sure if you are cheating or not, do not do it!

2. **Another important item – Rigorous and specific writing**: You should always focus on the clarity and readability of your write-up: ask yourself "can I write this sentence in a clearer way?" You should write your report with another specific goal in mind. This is to write in specific and rigorous terms, rather than general and vague terms. For a person actually involved doing the research, you may think that a sentence/paragraph is clear and specific enough, but that may not be the case for someone who is reading your work for the first time (who does not know the ins and outs of your work). You should ask the following questions for every piece that you write: Is it possible to revise and make it more specific? Can the reader interpret the piece here in a different, unintended way? Can it create questions in the reader's mind instead of/rather than answering them? In technical writing, you try to answer questions proactively – before even the reader comes up with them; and you try not to leave anything to reader's interpretation or guess. One idea could be to read your document after awhile (in a few days) or have a friend of yours read it for you, and see if you or your friend get the same point you intended to convey originally. In any case, when you realize that something is not specific and clear enough even in a sentence or a paragraph, I suggest two

alternative ways to address the issue: (1) you revise the sentence so that it is, by itself, clear and rigorous, or (2) you follow the sentence with explanatory sentences/paragraphs or give examples that answer the questions, eliminate unintended interpretations, and provide additional details.

One common mistake that many first-time writers do is to write in long, complex sentences and paragraphs. Write rather short and simple sentences. As I suggest above with alternative (2), if you need to put additional detail, put explanatory statements that are still simple and short right after the sentence that needs the detail. This will eliminate other related clarity and readability problems too.

Use active voice whenever possible: For example, prefer "*Figure X shows that …*" over "*It is shown in Figure X that …*"

Rigorous writing is especially true for statements that claim "*optimality*," "*best*," "*lowest*," or "*insert your superlative here*" among alternatives, solutions, or cases, whatever they are. If these statements are valid only under certain conditions, and/or only among the cases/solutions/scenarios/etc. considered, make sure you mention that explicitly. If there is any condition, qualification, and setting under which the statements do not hold, make sure you state that too. If these claims are only true "*approximately*" or "*only under special cases*," modify your statements accordingly (e.g., "*near optimal*", "*the best in 22 out of 24 cases considered*" "*one of the best*", or "*the lowest with 95% probability*").

Use formal language as much as possible. Use "obtain" instead of "take" or "get," use "provide" or "offer" instead of "give." Avoid informal language; do not forget technical writing is different from speaking or even giving a technical presentation: Informal words here and there in presentation may even be good, but technical writing especially for a report or paper should be formal.

3. **Citing others' work**: Use name and year style, for example: "*Smith and Doe (2002) study a similar problem with X objective*" or "*A similar problem with X objective is presented earlier (Smith and Doe, 2002).*" Do not forget to include the paper in your list of references in appropriate alphabetical order. Do not use numbers and non-alphabetical orders of references.

4. **Literature Review:** Your review should be brief. It should organize, categorize, critique the papers; explain their relevance to what you are doing, and position your work in the light of what you find in the literature. Every paper in your list of references should be properly cited. Every paper cited should be properly listed in your references. If you are citing other papers in other sections/chapters of your report, do not forget to include them in your references. (See the general comment about citing others' work).

5. **The flow of information**: The flow of ideas should be smooth and natural. The sentences, paragraphs and sections should be connected tightly and they should

follow a logical and natural flow. Modular writing is OK as long as modules are linked properly. Convey your logic or view using connecting words: *however, nevertheless, but, since, as, because*, etc. Include (but do not overdo) flow statements in the report: "*In this section, we analyze the properties of the model*."

6. **Mathematics and math models:** Define terms/symbols before you use them. When presenting your mathematical notation, define sets, indices, parameters, and decision variables explicitly and separately. Use indices and parameters consistently, e.g., if index symbol *i* denotes a certain element (say a job) of set *I* (say a set of jobs), then it cannot be used to denote anything else. You can keep a table of notation, to see what symbols you are using and what they mean. Once you define everything carefully, you can present your model, whether it is a math program or a set of mathematical expressions that use the defined notation. In Word, use equation editor (Insert-Object-Equation) to properly insert math symbols, and equations. Do not change the font size in the equation editor unnecessarily, and make sure the font size in equation objects match with that of the text. Number the equations/constraints so that you can refer to them in the text, e.g., "*Constraint (5) limits the combinations of …*" or "*Equation (23) uses the definition of …*" When you write an expression, explain what it does verbally, and then state it mathematically, always referring to the equation after the equation's mathematical statement (not before).

7. **Tables and figures**: Your tables/figures should be numbered sequentially. Each one should have an explanatory caption. Table captions should be on top of the table, figure captions on the bottom. Each one should be properly referenced in the text. Captions should have specific information regarding that particular table or figure (parameter settings, values of variables, symbols or acronyms used in the table or figures, etc). Use light or white backgrounds and simple symbols (circle, square etc.) in lines/curves in charts. Use symbols with borders and white fill (black foreground and white background in Excel for symbols). Large and detailed tables and figures can be placed in Appendix, but they should be properly referenced in the text in relevant places.

8. **Experimental Design**: Sometimes, you need to design a set of experiments to be able to test ideas, models, and scenarios. When you design experiments and write your design in your report, try the following:
    a. Identify what **factors** would affect your results – Try to include all possible factors so that you do not overlook an important one.
    b. Decide **fixed factors** – what factors would you like to keep constant, at what levels, and why?
    c. Decide **random factors** – what factors would you like to have randomly generated, with what kind of distribution, and why?
    d. Decide **controlled factors** - what factors would you like to change in a controlled manner so that you can analyze their effects explicitly, at what levels, and why?
    e. Prepare a table that lists your factors, their fixed or changing levels.

In deciding the factors and their levels, what you are trying to show in the report (the theme of the paper) becomes important. In deciding the levels of the factors, a real data set (if you have any) could give you clues, or some preliminary testing could be useful. Also use your common sense, intuition, and your theoretical knowledge to eliminate some factors and levels, or to narrow down the options. See the next item on problem/data generation.

9. **Problem/data generation**: If there is a well-established data set or problem library for your specific problem, use it, with citing the source properly. Sometimes, you need to generate your problem data, using some scheme, which is usually random but controlled. You should explain how you generate your problem data in detail, give an example if necessary, mention what you are keeping constant, and what you are randomizing, mention the number of instances you are generating under each experimental design point (a factor-level combination). Base your choices on others' work that are already published and accepted in the literature, if you can.

10. **Computational Study**: Keep in mind that not everything that you compute, run, or collect will go into your report. For example, the tests you make to validate or verify your model/code/data may take some effort and potentially long time, but they will probably a few sentences in your report just to give an indication that the tests are successful. One obvious way to test your model/code/data generation is to run it using small scale "toy problems" where you can easily calculate expected behavior. Another way is to run your code under extreme cases and special settings, where you can guess or intuitively/theoretically know/compute the results. For example, *when you run an inventory model with 0 stock level, does it give you zero fill rate*? Yet another alternative is to run it by changing certain parameters in a controlled manner to see if the model/code is behaving as expected. For example, *does the fill rate go down when you increase the lead time*? The most part of this testing will not go into your report, other than rather brief and convincing explanation of your tests that states the model is validated.

    As you usually run a number of experiments, you should take advantage of batch runs and automated output collection. Redirect the output in your code to files. Have detailed output during your run; you can always look at these details if you need to. Collect what you would like to analyze in arrays and other data structures and print them at the end of your run. For further analysis, all you have to do will be to copy and paste last certain number of lines from your output files, which is easier than finding different pieces of information from multiple places in your output files and putting them together. Try to format your output (in rows and columns) so that you can easily insert it in an Excel worksheet. Take advantage of batch runs in Command Prompt in Windows and batch runs in Unix/Linux to run multiple programs one after another, potentially directing their output to different files for further analysis. If you have an extensive set of outputs to deal with, I suggest a package called AWK (or its equivalents such as MAWK or GAWK), in which you can easily parse and format text from/to multiple files.

IV. Other Writing Rules

1. Check carefully for spelling errors. Do not trust your word processor's spell check utility. Read the document and check with a dictionary if you are not sure.
2. Read your draft at least twice after you think you are done making sure that all the rules here are satisfied by every line/sentence/paragraph of your paper.
3. Use "work" instead of "works." "Prior/related work" when referring to the literature, not "prior/related works."
4. Use "notation" not "notations."
5. Check the usage of singular and plural nouns and the use of articles. "*We locate facility in supply chain in this problem…*" is not correct. If you are actually locating multiple facilities "*Locating facilities in a supply chain …*" is correct. If you are locating one facility, then "*Locating a facility in a supply chain …*" is correct. If you are referring to a specific supply chain that you introduced earlier in the text, use "*the*" before supply chain. Here is another example that is correct: "*Locating facilities in the supply chain design problem is handled by binary variables.*"
6. Check if the verb in the sentence corresponds to the "subject" (the noun that acts the "verb"). Correct examples: "*Facilities are locations that stock parts*." "*Given a network, locating facilities is a hard problem*."
7. Use a comma before the last phrase if there are multiple phrases separated by commas in a sentence. Use "*and*" before the last phrase. Place the comma before the "*and*." A correct example: "*We provide an extensive computational study that demonstrates the use of the developed method, shows the sensitivity of the objective to certain input parameters, and provides evidence that the method can be used to solve large-scale problems.*"
8. Quotes must be closed outside the punctuation marks. See examples above.
9. Do not use contractions. Use "*do not*," "*cannot*," etc. instead of "*don't*," "*can't*."
10. Do not start a sentence with "*Because*" or "*And*."
11. Avoid using the symbol "&" in place of "*and.*"

V. Special Treatments:

1. **If you write a program for your computational experiments and/or data generation**, write a user's guide (similar to a readme file found in normal software packages) that explains the process of running the program, inputting the necessary data, obtaining the output, and other steps in your specific program. Include information about file/folder naming conventions you use. Put this in an appendix and cite it in an appropriate place in your main text. The idea in here should be that a student should be able to read your report, use your program, and start his/her research from the point you left off without too much difficulty and too many questions to me or to you.

VI. Other strategies to improve your productivity and writing

1. **Read, read, and read**: Read technical papers and news and magazine articles. Of course, you will read the papers in your area more carefully, but even when you

read other articles, try to pick up styles, usage conventions, etc. Critique while reading. If you are an international student, this activity will improve not only your written English, but also your speaking and listening.

2. **Listen, listen, and listen**: When you listen to the radio or watch TV, follow the suggestions above for reading. For radio, I suggest National Public Radio (NPR) that broadcasts US and world news most part of the day. It gives you a great occasion to listen while you are in car or at home.
3. **Keep a log**: As you work on your research, keep a log of what you are doing along the way, in parallel to your research, literature review, or computation work. This "live" document will form the backbone of your final report/paper. As you progress, you gradually fill your literature review, modeling, analysis, experimental design, and data generation sections. These parts are usually easier to write. You can always revise these parts as you progress and improve your style. Moreover, use your log to jot down your ideas, the things you would like to try, important items from our meetings, etc. so when the time comes you can go back and address them. Share well written parts of this document with me, and I will give you feedback. This will help improve the quality of your final report.

VII. Other resources:

A must read: Strunk and White, *Elements of Style*.
http://www.bartleby.com/141/index.html

Check out and use the UT Learning Center's Graduate Student Writing Service:
http://www.utexas.edu/student/utlc/tutoring/grad_writing_services.php

Check out the online writing center resources at other universities:
Purdue's Online Writing Lab (OWL): http://owl.english.purdue.edu/owl/
Stanford University's Writing Center: http://swc.stanford.edu/

Writing Rules and Tips from Other Professors:
http://www.cs.columbia.edu/~hgs/etc/writing-style.html

See the following references about how to present computational work in OR/IE:

J.N. Hooker (1994) "Needed: An Empirical Science of Algorithms," Operations Research, vol. 42, no. 2, pp. 201-212.

B.W. Lin and R.L. Rardin (1980) "Controlled Experimental Design for Statistical Comparison of Integer Programming Algorithms," Management Science, vol. 25, 1258-1271.

R. Rardin and R. Uzsoy (2001) "Experimental Evaluation of Heuristic Optimization Algorithms: A Tutorial," Journal of Heuristics, vol. 7, no. 2, pp. 261-304.