Some Advice for Research Students

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In a group discussion about the experiences of graduate students in signal processing at the University of Illinois at Urbana-Champaign (UIUC), Prof. Pierre Moulin listed ten qualities of an ideal Ph.D. candidate: intelligent, creative, proactive, driven (motivated), confident, good communicator (oral & written), independent, hardworking, well organized, and able to work with others. People in that meeting agreed that while some of these qualities we are born with, fortunately many other qualities can be obtained through practice.

In this note, I offer some advice on the three most important qualities, using my personal experience as a graduate student and then a faculty. These are: *writing skill*, *presentation skill* and *being proactive*. I also suggest a concrete action plan to regularly practice these skills. Comments or suggestions are welcome.

1 Writing Skill

Writing skill is an essential quality of a research student. While there are many other factors, the productivity of research nowadays is measured mainly in terms of the number of *papers in high quality journals*[1]. These products will ultimately be the result of an excellent writing skill. However, it is important to keep in mind that not all of our writing has to be in polished form for publication. Majority of our writing will be research notebooks, weekly reports, and paper drafts. Hence, a great benefit of developing writing skill is that **clear writing leads to clear thinking**.

So how can we improve our writing skill? Following are several activities that I found useful:

- First, you need to **have some good books on writing**. These books typically contain the basic rules in writing, as well as plenty of good tips on how to write well. Here are some of the books that I use frequently and keep within a close reach whenever I write.

  1. Higham, *Handbook of Writing for the Mathematical Sciences*, 2nd ed., SIAM, 1998.
     This handbook is highly recommended and should be on the reference shelf of any research student. The book covers a handy set of rules and provides advice on technical writing. It also overviews the entire publication process, which is invaluable for anyone planing to publish in a technical journal.
  2. Strunk and White, *The Elements of Style*, 4th ed., 2000.
     This little book is a classic and "should be the daily companion of anyone who writes." It presents a concise set of rules and principles, together with examples, about English writing. *Elements of Style* is available on-line[2] at `http://www.bartleby.com/141`.

[1] In our field, the most most respected journals are the IEEE Transactions on Signal Processing and IEEE Transactions on Image Processing.

[2] From `http://www.bartleby.com` you can also access to other essential writing resources, with their search facility, such as *American Heritage Dictionary of the English Language*, and *American Heritage Book of English Usage*.

3. Zinsser, *On Writing Well*, Collins, 2006.

   Another classic guide for nonfiction writing.

4. Schimel, *Writing Science: How to write papers that get cited and proposals that get funded*, Oxford University Press, 2012.

   This book provides excellent insights and strategies for successful science writing, which is similar to telling a story that is sticky.

5. Alley, *The Craft of Scientific Writing*, 3rd ed., Springer, 1996.

   This book offers excellent discussion and useful suggestions about how to bring your idea into strong writing.

6. Dupre, *BUGS in Writing: A Guide to Debugging Your Prose*, 2nd ed., Addison-Wesley Pub Co, 1998.

   Another good book that has writing advice and examples.

In addition, a good English dictionary is indispensable. Since I do most of my writing directly on computer, I find computer-based dictionaries are very useful, because of their search facility. Computers on the UIUC network have access to the *Oxford English Dictionary* via http://dictionary.oed.com. There are also many other dictionaries available on-line, such as http://www.m-w.com and http://www.dictionary.com.

- As you would learn to program best by studying and imitating programming examples, good technical writing skill requires **reading lots of technical papers**. If you plan to write papers for a journal, say the IEEE Transactions on Image Processing, then you need to read many papers from that journal to get an idea about the common style, level of details, structures, length, format, etc of its papers. From a computer on UIUC network, you have electronic access to all publications by IEEE via IEEE Xplore at http://ieeexplore.ieee.org. Another resource for papers online is https://arxiv.org, in which you can subscribe to the e-mail alerting service to receive regular listings of the abstracts of new submissions in chosen subjects. These listings help you to keep updated with current research in your field.

  Note that even in journals, not all papers are well-written. When reading either a strong or weak writing, try to figure out why so. Remember these observations when you are in the other role as a writer. A golden rule in writing is **always keep the audience in mind**.

- Start a habit to note down phrases, constructions in papers/books that you find useful so that you can apply them later to your papers. Doing so you could avoid being plagiarism. *Never copy a whole sentence from other author(s) into your writing unless you want to quote*. In addition, try out to see what writing constructions work best for you. In the end, you have to develop your own writing style.

  In general, **keeping a notebook with you all the time** to record ideas, thoughts, observations, daily activities and so on are strongly recommended. Our short-term memory only can keep about 7 pieces of information at a time. So good insights, unless getting noted down, will be lost.

- Practice, practice, and practice! The best way to improve writing skill is to practice it regularly – a more specific action plan about this will be followed shortly. A well-known writer even said that you should treat writing as "taking a dog out for a walk !" That means you need writing something (even as little as one paragraph) every day to keep up with the practice.

- Revise, revise, and revise! Revision mean "re-seeing." Remember the writing task does not end after finishing the first draft. **Revision is the key for good writing**. Revision is not just about spotting grammatical and mechanical problems, but it is also about "seeing the big picture and the overall

effect." Chuck Guilford offers the following excellent advice about revision on the Paradigm Online Writing Assistant Web site (http://www.powa.org).

> Knowing you'll revise, you can relax and speak your mind early in your writing process. Since your words can be changed later, you won't worry about writing the perfect first draft.
>
> That's one important difference between writing and speaking. When you speak, you get only one chance. Whatever you say, appropriate or not, has been said. Maybe that's why we have the sayings, "Think before you speak," and "Make sure brain is in gear before engaging tongue." If you write something inappropriate, however, you can change it, or even tear it up and throw it away. With writing you get a second chance, or a third or a fourth. And each time you revise, you find new potential in the evolving text.
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> Too often, inexperienced writers don't see this potential. They are too careful and self-critical at the start of a project and too easily satisfied toward the end. Having agonized through a first draft, they quickly check for grammar and mechanics and consider themselves done.
>
> More experienced writers usually do just the reverse. Early on, they work at discovering what to say, getting their ideas out onto disk or paper. They write quickly, accepting chance discoveries, trusting hunches and gut-feelings, willingly making mistakes. Gradually, though, they feel a need to look back over their work, to ask whether it makes sense, how their readers will respond. Thus begins the process of revision.

- Try to **get help and feedback on your writing**, especially if you are non-native English speaker. In that case, it is ideal if you can find a native English speaker who would be willing to proofread your writing. For this, the Writers Workshop at UIUC (http://www.cws.illinois.edu/workshop/) offers an excellent resource. From its Web page, you can also find many links to other resources on-line.

  Print out your writing in double-spaced format and ask someone to comment on it using a color pen. Study and keep these notes. You will soon discover the common problems that you have in writing, such as incorrect use of prepositions or omission of the ending 's'. Work hard on fixing up these problems by yourself in revising. Also, remember to thoroughly revise a writing by yourself at least once before giving it to someone for comments.

2 Presentation Skill

Presentation skill is required in all forms of oral communication, ranging from discussing research problems with other researchers to presenting papers at conferences. Apart from regular meetings with your thesis advisor, you should frequently discuss your research with your peers, other faculty, and even people outside your area to get feedback from different perspectives. Good presentation skill will maximize the benefit from these discussions. During your time as a graduate student, you will have plenty of chances to present research to your colleagues, faculty members (some will be on your thesis committee), audience at conferences (some could be your future employers). You should seize these occasions as great opportunities to demonstrate your research and communication capabilities. Most of the leading researchers are also well-known for being excellent presenters.

Following is some advice for improving presentation skill.

- Seek opportunities to practice your presentation skill. **Talk often to your peers about your research**. If you can present your research/idea in interesting and accessible ways then people would keen to hear about it and more likely to give useful feedback. The most simple yet highly effective way is to regularly discuss research with another peer in front of a board. In this you try to clearly and succinctly explain a research problem or idea by both speaking and writing on a board at the same time. This skill is crucial for a good researcher and teacher and is currently tested at the ECE PhD qualifying exams.

  Next, volunteer to give talks in seminars. One way is to organize weekly seminars or journal clubs with a group of graduate students who shares common research interests and each person in turn would select and present a seminal paper in the field.

- Like reading is an excellent way to improve writing skill, **attending seminars** is an excellent way to improve presentation skill. There are plenty of seminars on the campus during the semester and you should take advantage from these seminars. Apart from our weekly group seminar, the most relevant ones to us are the Signals, Inference, and Networks (SINE) Seminar and the ECE Colloquium at UIUC. Come to these seminars to learn new developments in closely related fields. Also observe the presentation techniques of speakers, and find out what work and what don't. You will find the common mistake in many talks is that they are too complicated, too detailed, and thus loose the audience and don't show the big picture. Remember to avoid this mistake when preparing for your own talks.

- If you are a non-native English speaker, you should consider taking some oral communication courses. Even native speakers benefit greatly from public speaking course (business people often do this). The University of Illinois offers several ESL (English as a Second Language) courses. Check the International Student Office for more details about these courses.

- Prepare for a Teaching Assistant (TA) job. I consider **taking TA appointments** is an important part of the PhD education. This is of course essential if you plan to get an academic job. But also in many other occupations, the ability to explain difficult concepts to other people is essential. If you are a non-native English speaker, you need to pass the SPEAK test to be qualified for a TA job at UIUC. Find out the requirements and consider taking the SPEAK test as soon as you can.

3 Being Proactive

Being proactive means "acting in advance to deal with expected difficulty". Working on a PhD thesis is certainly a very difficult process. It requires formulating the right problem, finding feasible solutions, and conducting simulations to confirm the theory/intuition. While the thesis advisor can provide initial direction, **the PhD candidate has to be in charge and lead the process**.

New graduate students often find it is difficult to be proactive in research, especially in coming up with new research ideas. **One way to get a few good research ideas is to generate lots of ideas**.

- **Read widely**. Reading, in my opinion, is the best way to learn. However, to get the most benefit out of reading, you have to read with a critical mind.

  First, for reading there is a vast literature out there on any topic, so you need to be selective of what to read. Prof. Doug Jones offers excellent tips on using the library for research at http://www.ifp.illinois.edu/~jones/library.html. He suggests to start general, then specific. If you are new to a field and that field is mature enough to be covered in books, then you should start from there. Library search facilities will help you to find these books. For more

specific or current topics, you may only find the desired material from papers in journals or conference proceedings. Fortunately, in our field most of these articles would be published by IEEE, and thus the IEEE Xplore website mentioned before with its search facility is an indispensable resource. Another resource is search engine like Google Scholar (http://scholar.google.com), since many people make their work available on-line. For example, if you are investigating "directional filter banks (DFB)", then these search facilities could provide answers to some crucial questions like "what has been done with DFB?", "what are the latest developments in DFB research?", or "what are applications of DFB?".

Next, for critical reading the most important thing is to **read with an active mind** rather than with an passive mind (i.e. only absorbing the information). Keep asking questions like *why did the author(s) do this? How did they come up with this idea? What is the key intuition behind this technique? How could we do it differently? What happens if we change the assumption to...? This is a great idea, how I can apply it to my problem (could be in a completely different field)?, etc.*. Write all of these comments/ideas down. Don't just trash an idea right away because you "feel" it is not feasible or invalid (e.g. based on assumption that you don't have enough background in that area). First, list all of your ideas; then revise and modify them regularly later. Keep in mind that good research is based on **asking the right questions and refining them**.

Another good tip is to read and re-read some of the classic papers in your research area from time to time. These papers are often very stimulating and inspire new research ideas.

- **Get insight from data and experiments**. If you find an interesting algorithm or method, go ahead and implement it and test it on your data. For example, when I learned about ridgelets and curvelets, I wrote nearly a hundred Matlab programs that examine different aspects of these transforms. I then printed out the results, stuck them on the wall, stared at them every day, and then eventually ideas for improvements and novel methods came up.

- Talk and seek comments/feedback from other people. Doug Jones, on his library search Web page, suggests the following excellent tip:

  > Tip #5: **Ask the experts**: At the University of Illinois, you are blessed with one of the largest and most knowledgeable body of scholars on Earth, including not only the faculty but also staff, graduate students, and undergraduate students. Ask around, find out who the experts are on the topic of interest, and go talk to them. Most scholars greatly enjoy sharing their knowledge with others who have a genuine interest, so take advantage of this! However, keep in mind that you need a basic understanding of the area to frame the right questions and to understand the answers you get, so experts are not a complete substitute for written resources. Use them like the more specialized material mentioned in Tip #4; prepare yourself first to take advantage of their expertise. But, don't be too shy about approaching them, either!

4 Online Resources

There are many excellent resources for graduate students and researchers on the Web. Here are some that I found very useful:

- **Succeeding in Graduate School**.
  http://www.phds.org/graduate-school-success

- **Graduate Student Resources**. "Useful tips on how to succeed in graduate school and your subsequent research career (somewhat slanted toward signal processing)."
  http://richb.rice.edu/signal-processing/research-resources
- **Graduate Student Resources Page**.
  http://www-personal.umich.edu/~danhorn/graduate.html
- **Advice on Research and Writing**.
  https://www.cs.cmu.edu/~mleone/how-to.html
- **How to Succeed in Graduate School: A Guide to Students and Advisers**, by Marie desJardins.
  https://www.csee.umbc.edu/~mariedj/papers/advice.pdf
- **"So Long, and Thanks for the Ph.D.!"**, guides for surviving graduate school by Ronald T. Azuma.
  http://www.cs.unc.edu/~azuma/hitch4.html

5 Action Plan: Weekly Report

In order to practice these above mentioned skills, I recommend the following activity for graduate research students in my group. Every week, each student should write a one-page report summarizing the main research findings of the week and providing the working plan for following weeks. We can think about these weekly reports as journals of research activities. Exemption for this rule is when you are writing something else like a paper or thesis and you can turn in a draft for comments instead. The benefit of writing weekly reports is twofold. First, it serves as a bookkeeping of your activities and new ideas (e.g. after reading a key paper), and provides a write-up that can be used later in papers, your thesis, etc. Second, it offers a regular writing exercise. Thus, the reports should be written in the style of a scientific paper.

Following is an example format for the weekly reports:

Statement of Problem/Abstract: A concise description of the current research problem/paper(s) that you are working on.

Main Findings: Describe your main findings of the week. They can be a summary in your own words of the relevant results from research papers that you read during the week; new ideas/suggestions for improvement; a discussion of a new set of experiments that you conducted and the results that you obtained; new theorems or conjectures.

Future work: What would be the next steps based on the current results/findings. If possible, sketch a time table for these steps.

Appendix: If necessary, attach copies of plots, proofs, etc.

A Appendix: Using LaTeX for Writing Papers

If you have not done so, you should learn how to write technical documents in LaTeX as soon as possible. Apart from producing very professional looking documents, especially with mathematical formulas, LaTeX makes it very easy to format your papers to meet guidelines of conference proceedings, journals, thesis, etc. Also, you can easily change from one format to another, for example: conference paper $\rightarrow$ journal paper $\rightarrow$ thesis. Moreover, since most of the researchers in our field write in LaTeX (as I do!), if you also do the same then it becomes very convenient to combine writing with other people in co-authored papers. Finally, since you would write using a plain text editor, LaTeX helps you to focus at the content first instead of worrying about the format.

You can easily get LaTeX installed in your computer using a free distribution from the *LaTeX Project* website `https://www.latex-project.org`. Although having a LaTeX book on your desk is crucial (the recommended one is *Guide to LaTeX2* by Kopka & Daly), for start a short introduction is sufficient. For this, the on-line document *The Not So Short Introduction to LaTeX* is excellent. Also, ask friends to give you some of their LaTeX files to use as a template. Paper templates for conferences and journals are often provided on their websites.

You will very soon have to include graphics into your papers. The on-line document *Using Imported Graphics in LaTeX and pdfLaTeX* contains most of things you need to know about this. You should be able to search for the aforementioned on-line documents using their titles.

For drawing figures, you should use a vector graphics editor like `Inkscape` or `xfig`. I keep all of my figures, drawn by `xfig` and then exported to EPS/PDF files or generated from Matlab/Python programs, in a directory that can be shared by several papers and presentations.

Finally, for citing references, BibTeX is a powerful tool. It helps you to maintain a database of papers/books when you read and survey the literature, then use in LaTeX documents, and also share with other LaTeX users. Here is an useful convention in naming the bib-item: it starts with the name of the first author, followed by the last initial of other authors (if any), then ':', and the last two digits of the published year. For example:

```
@BOOK{BurrusGG:98,
 author =       {C. S. Burrus and R. A. Gopinath and H. Guo},
 title =        {Introduction to Wavelets and Wavelet Transforms: A Primer},
 publisher =    {Prentice-Hall},
 year =         {1998}, }
```

Following this naming convention will help you to cite a reference in your paper without checking the BibTeX files.