Stuff most students never ask about grad school

Rob N. Candler

To go or not to go...

To make this decision about graduate school, you need to take a careful look at your motivating factors. Many of my friends (and myself) graduated with a B.S. in engineering feeling that we really didn't know what to do with all the equations we had learned. A professor from my undergraduate years gave me a good analogy. He said that you're given a toolbox at the beginning of your undergraduate education. Each class you take gives you a tool for your toolbox. So, the question you're really asking yourself at graduation is "What do I do with all these tools?!?" I think an M.S. gives you a few more tools, while allowing you to use some of the tools you already have. A Ph.D. enables you to build new tools.

In getting an M.S., you take advanced courses in areas of interest along with some project-based classes to gain experience solving more involved problems. Also, some universities have the option (or requirement) of performing a research project and writing a thesis describing the work.

A Ph.D. involves coursework requirements similar to that of the M.S. and may even have some additional course requirements. The major distinction occurs with the dissertation. The Ph.D. dissertation is a much more involved research project that should push the frontiers of knowledge in the chosen field. It should involve doing something that no one else has ever done before.

Common motivations for getting an M.S. include a desire for a higher salary or to specialize your skills so you can work on a different set of tasks or maybe you were really interested in a class you took and want to learn more about that subject area. Common motivations for getting a Ph.D. are being able to work on a different set of tasks and the opportunity to work in a more research-oriented environment versus one geared towards developing and manufacturing products. Also, there are people who are jokingly called *terminal students*. They love learning new things.

An important point to stress is that additional degrees do not increase the number of jobs available to you. In fact, additional education may *decrease* the number of jobs available because you will be considered overqualified. Also, there are fewer jobs that require a Ph.D. as compared to an M.S. Similarly, an M.S. may limit your job choices as compared to a B.S. (I know friends with a B.S. have used their general problem-solving skills to get all types of jobs including jobs outside their major.)

A special subset of Ph.D.-enabled tasks is academia. Many people, including myself, would like to teach and lead research in an academic setting that for most technical fields requires a Ph.D.

A higher salary is not necessarily a good motivation for a Ph.D. Getting a Ph.D. can take several years, and the loss in income during those years may counter the increased salary upon graduation.

Internships are a great opportunity to get an idea of the tasks worked on by M.S. and Ph.D. engineers. These

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experiences can help you decide which of these careers and degrees are best for you.

Okay, so you're going to graduate school...

The next step is deciding where to apply. Applications are generally due some time around December the year before you plan on starting school. Many people apply to five or six schools because they may not be certain where they want to attend or to which schools they are likely to get admitted. The two major steps early in the application process are: 1) taking the GRE (Graduate Record Examination) and 2) finding people to write you letters of recommendation. You should take the GRE with sufficient time for the scores to be sent to the schools to which you are applying, and you should give at least one month to those people who are writing you letters of recommendation.

The criteria for selecting a graduate school can generate a heated debate. I asked three trusted friends for their school selection methods, and I got three distinct answers. The first told me to go to the most prestigious school to which I could get accepted. His reasoning is that graduating from a prestigious school makes the job search, especially a faculty job search, easier upon graduation. The second friend told me that if there is one particular person I wanted to work for, I should go to that school. He also said that if there was no particular person I wanted to work for, I should go to the best school that would accept me because it most likely would have someone I could work for. The final person said I should find a location where I would like to live and find a school there.

My graduate school selection was based on parts of advice given to me by all three people. I think a well-respected school is advantageous in the post-graduation job search. I also believe professors at highly rated schools have an easier time raising funding to pay for their graduate students. As for the advice of my third friend, "location, location, location," I think it is certainly something to consider, although I do not place as much weight on it as he did. One caveat here: My friends in M.S. programs, which typically take one to three years to complete, are generally less concerned about the school location as compared to people in a Ph.D. program, which can take five to seven years. Contrary to the belief of some advisors, there is life outside the lab during graduate school.

In fact, a few enjoyable activities outside of your research may actually increase your productivity, because you will generally have a more positive attitude, which could help you avoid burnout. Outside activities can also have a more direct impact. Getting some distance and perspective from a problem you have been struggling with is often the quickest way to solve it. Some of my best research ideas have come to me while running stairs at the stadium. Finding a school that provides the opportunity for you to enjoy your "off-time" is worthwhile.

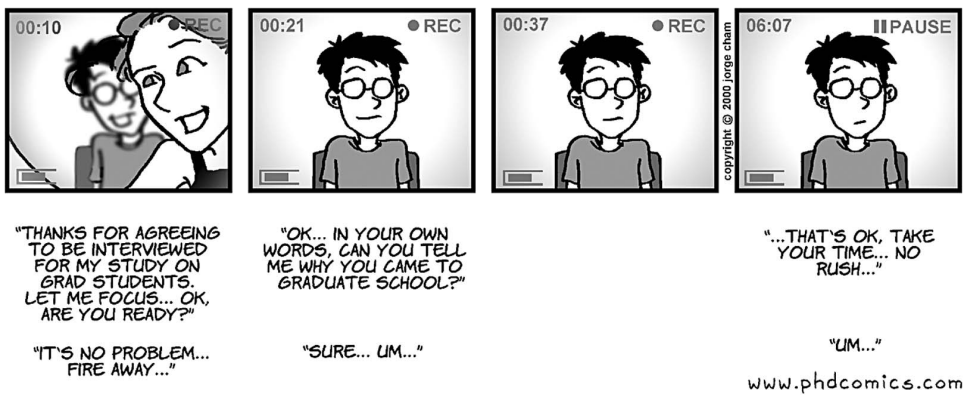
As for the second friend's advice about finding a person you want to work for, I think this is a potentially risky strategy. Two friends come to mind who that have had difficulty from using this strategy. One selected a school because the advisor was the leader in his field, but upon his arrival, he discovered that there were ethical differences that prevented him from working with that person. The other friend found out after his arrival that the advisor would be unable to obtain the necessary funds to sponsor him as a graduate student.

But just because I'm against putting all of your eggs in one advisor's basket does not mean you shouldn't check out the school's subject areas of focus. It is important to make sure that the schools where you apply have research being conducted in your area of interest (if you know what your area of interest is). Ideally, you should be able to identify two or three possible advisors at the school. Schools handle student-advisor assignments in different ways. Some will admit you and then expect you to find an advisor on your own. Others will admit you with the assumption that you will work for a particular faculty member. If you apply to a school that follows the second policy, I would recommend finding out as much about the advisor as possible before you decide to attend that university.

Funding

Graduate school is expensive—and you probably didn't become a millionaire as an undergrad—so how do you get through graduate school without piling up massive debt? Luckily, finding funding as a graduate student is often easier than finding funding as an undergrad. Funding comes in many different flavors, including teaching assistantships, where you assist a professor with a course he or she is teaching, research assistantships, where you perform research on a specific project, and fellowships. Departments may help you attain one of these types of funding. You also can help yourself. For example, you may have taken several classes in a specific subject as an undergrad, making you a good candidate for a teaching assistantship in that area. (Note: alternative sources of funding exist, such as working in a laboratory on an hourly basis or grading papers for a large class.)

Since you are already mired in reams of paperwork, you may as well add a little more to the stack by applying for fellowships. They are the same as tuition scholarships with the addition of a stipend for living expenses. Universities may give fellowships to students they consider highly qualified. There are also several fellowships that are not associated with any specific university. Be aware that many of these fellowships are available. Winning one of these external fellowships will help you gain admission to and proceed through any institution. It is certainly worth your effort to apply. In many ways, the fellowship applications can be more



important than school applications. A fellowship allows you a high degree of freedom in whom you select as an advisor. Who would say no when you're offering to work for free! With a fellowship, you may also have more freedom regarding your research topic, because an advisor doesn't need to immediately have a source of funding for your work. Also, some fellowship programs accept applications from students already in graduate school. These are definitely worth applying for!

Advisor selection

If you plan on doing research, the person you select as an advisor is the most important decision you will make while at graduate school. One piece of advice offered to me by several people, which I found hard to believe at first, is that in terms of advisor selection, *the person is more important than the project itself*. In fact, finding a person you can work well with is *far* more important, in my opinion (and the opinion of many who attended graduate school), than finding a person with the "perfect" project or a project similar to what you were working on as an undergraduate. Just because you focused on one very specific topic in your undergraduate research doesn't mean you're married to that topic. In fact, your advisor may not be directly in your field of study (assuming your school allows interdisciplinary study). For example, I have an electrical engineering background, but my advisor is in the mechanical engineering department. He's actually a physicist by training, but that's another story.

If you are faced with several advisor choices, you will be inclined to take the scientific approach of collecting data, analyzing this data, and coming to a conclusion based on this data. This approach can work. However, this is a matter of interpersonal relations. The things you need to consider are: 1) How/Who should I ask questions (what is my experimental setup)? 2) What questions should I ask to get useful information (what is my input)? 3) How should I interpret the answers I get (how do I analyze my data and filter out the noise)?

My answer to the first question would be to go to the closest sources: the advisor and some of his or her students. Meeting with a potential advisor is probably best done in a formal setting, in his or her office for example, because it is the most convenient for that person. For the graduate students of a potential advisor, I recommend an off-campus meeting. Students are more likely to be candid if they are not sitting in an office a few doors down from their advisor.

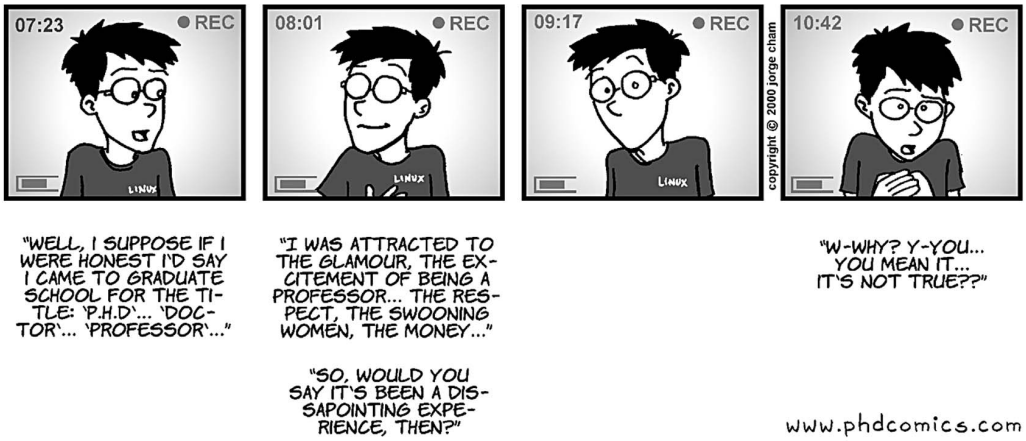
In fact, offering to take a graduate student to lunch has a high probability of success. Graduate students are rarely independently wealthy and are frequently hungry. In fact, I once had four rooms of furniture moved for two large pizzas. I also had my home wireless network overhauled for a fish sandwich, a cheeseburger, and two milkshakes. In short, never underestimate the power of food when it comes to graduate students. (A short side note to any advisors reading this: meetings with free food are much better and more enthusiastically attended than meetings without.)

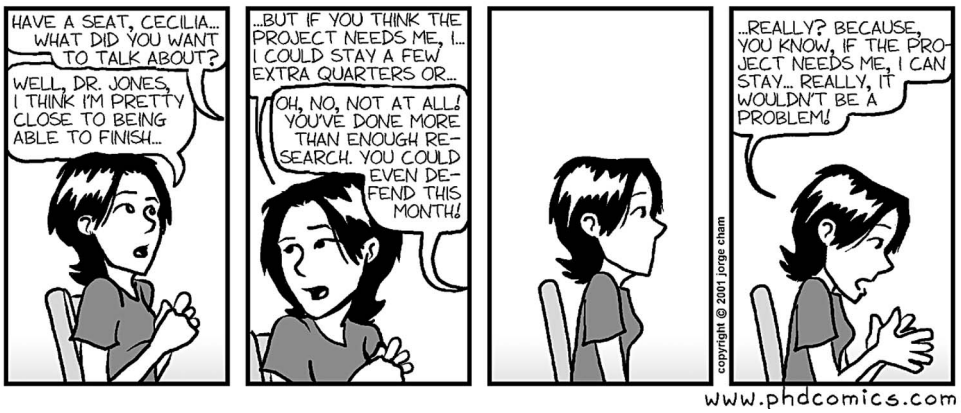
Now that you know whom to ask, it is just a matter of what to ask them. You'll find that you can get a lot of good information by simply asking directly. When talking to a potential advisor, remember that he or she wants a good advisor/advisee match as much as you do, so ask about current research projects and get a feel about the level of funding an advisor may have for new students. Also, keep in mind that this "face time" could help when the advisor is thinking about admitting new students into the group.

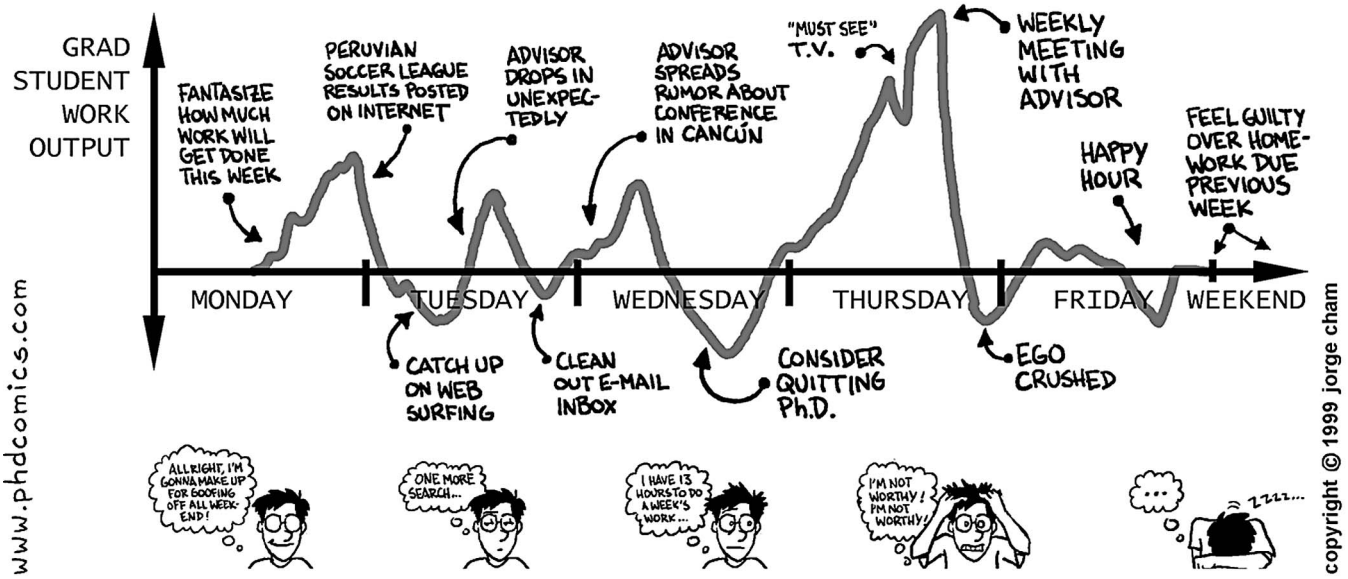
Don't be afraid to ask lots of questions, especially if the advisor is telling you about some of his or her research. You aren't expected to know everything. Also, it will show the professor that you are motivated, smart, and interested.

As for the meetings with the students of an advisor, there are several questions you can ask to get a general feel for how the advisor runs his or her group. One good piece of quantitative information is the average time students take to graduate. I would recommend neglecting the top and bottom 10% or so of the data, as outliers in this case are often the cause of the student and not the advisor (i.e., some students just don't want to leave the relative comfort of graduate school).

You can ask how helpful the group members are to each other. Having a good relationship with the people in your research group is important. If you







can do the work up front to find a group that works well together, you will benefit in the long term. My all time favorite question is, "Would you choose this advisor if you had it to do over again?" As a prospective graduate student, I asked this question to several fourth- and fifth-year students. I didn't get the across-the-board yes's I had expected. In fact, I got a majority of no's, along with explicit reasons.

The amount of time an advisor spends with his or her students is also good to know. Advisors may have periodic group and/or individual meetings with their students. The period of time between these meetings is of interest to you, depending on whether your work style is interactive or independent. Also, how available is their advisor when needed? Is he or she in the office regularly for questions? Available via e-mail for questions?

Different advisors have different management styles that range from hands on to letting you do whatever you like and giving advice only when asked. The type of advisor you seek is up to you. One good measure of the level to which an advisor manages his other group is the number of time requirements imposed. Some advisors let you work whenever you want, as long as you get the work done. Some would like you to be in the office during certain hours during the day to guarantee that you interact with others in your research group. Also, this way they can find you if they need something. Other advisors take role on a daily basis and may explicitly state the number of vacation days you are permitted. There is not really a right or wrong style here, just different styles and personalities.

Also, you want to know how the advisor gets funding for his or her students. A great mentor will have trouble producing great graduate students if there is no money to get the students through school. Specifically, ask about how the students are funded in the summer and whether they are predominantly teaching assistants, who are required to work part-time in support of a class, or research assistants.

Finding an advisor who encourages attendance at academic conferences is a good thing. Academic conferences are a great place to network, which is important for your career in either academe or industry. Also, do the students publish their work in respected journals? It has been said that publications are the currency of a good research program.

Don't be reluctant to "trust your gut feeling." If you didn't enjoy the first meeting and don't look forward to the next one, this is an important clue. Your relationship with your advisor will be tested along the way. Grad school is full of emotional peaks and valleys. You need to be comfortable when dealing with this person at all times.

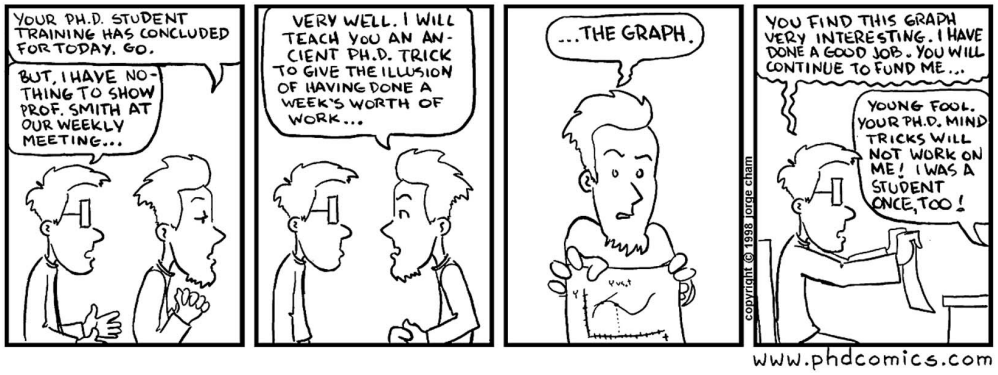
If a particular advisor makes you uncomfortable from the start, you should think about finding another advisor. If you make what you think is the right choice but later realize that you have made a mistake, don't be afraid to change. This may set your graduation date back a bit, but you will be happier if there is a good working relationship.

Meeting with your advisor

Having regular one-on-one meetings with your advisor is a good thing, if both your schedules permit it. (If this is not possible, bouncing your ideas off a colleague can be helpful as well.) Regular meetings will help keep you going in the right direction with your research, which will reduce the time you could potentially waste on dead-end ideas. When you go to meet with your advisor, it helps to have some sort of printout/handout that shows results from what you have been working on. It shows your advisor that you've been actually working. It will also help your advisor give constructive feedback, as it is easier to understand an explanation with visual aids than it is to understand an explanation without them. (Imagine attending a class where the teacher wasn't allowed to write anything on the board or show any slides!)

Group mates

Typically, you will work with a primary advisor who advises a group of students who are in similar fields of study. This group of people is often referred to as the research group. I think of these people as your group mates. Some people believe that your group mates are the most important people at your school, even more important than your advisor. While that opinion is debatable, it is rather obvious that these people are the most accessible to you. Quite often you share office and/or lab space with them and see them on a daily basis. They are knowledgeable and current in your field, and they are readily available.



Everyone will benefit if you all can give constructive feedback on each other's work. The less self-conscious you feel around your group mates, the more helpful everyone can be for each other.

So, don't be hesitant about interacting with your group mates. Many of my best ideas have come from casual chatting with my group mates. Social interaction also helps work to be more fun. Sharing an office with people is generally more enjoyable if you know and like them. Also, having a friendship with your group mates invests you in each other's well being, making you more likely to help each other in times of need.

Industrial collaboration

You may not have much control over whether or not collaboration with the industry takes place. What's more, the quality of collaboration can vary, so there aren't any generalizations to be made here. However, there are some possible pros and cons. Pros include the funding that often accompanies industrial partners, access to high-quality testing equipment that you may not have access to otherwise and the additional credibility that often comes with an industrial partner. There are several aspects that could be a pro or a con, depending on the circumstances and your personality. For instance, this additional mentor can provide useful guidance or just be another manager demanding a bunch of your time.

Also, industrial collaborations are often accompanied by a much more structured project. This can be a good thing in the sense that the project has a set direction with definite goals and real-world applications. It can be a bad thing for people who believe that structured projects limit their creativity.

A potential con of industrial collaboration is the restriction of publishing that can occur. Information is valuable to companies, and they aren't always interested in giving it away. They may want to carefully screen any joint work you wish to publish, requiring you to send an early draft to them with enough time for it to pass an approval process. Sometimes they may not want to have it published at all. Whatever the case may be, it would be wise for you to find out their rules on publishing early on.

Self-doubt and sticking out

All the content for this section came from helpful discussions with engineering colleagues in underrepresented groups. However, after I wrote it, it was pointed out that this information is useful for everyone.

There are two phenomena that are common among minority students in engineering. The first is the "imposter syndrome." Imposter syndrome is basically feelings of self-doubt that manifest themselves in thoughts such as, "Do I really deserve to be here? Everyone else is so much smarter than I am!" Actually, virtually all students have these feelings at some time during their schooling. They can result from general insecurity, thoughts that you were admitted to fill some sort of quota, or going to a major university for graduate school after graduating from a lesser-known undergraduate university. The list of reasons why people worry is long. The important thing to remember is that you were admitted because you were a qualified applicant. If the school didn't think you were well suited to attend, you would have gotten the thin rejection envelope instead of the thick acceptance one.

The second phenomenon is called the "minority spotlight," suggesting that you are much more recognizable if you are a less than common race or gender. This can actually be a good or a bad thing. On the positive side, a good talk at a conference or a good performance in class will be more readily remembered. On the negative side, you're more likely to get noticed if you skip class!

There are several things you can do to ensure that your experience in graduate school is a good one. The first one is to establish a community. Just as establishing a good relationship with your group mates helps, finding a group of students you can closely identify with can be valuable. Seek these people out and talk with them. Fortunately, many of these groups already exist. A female colleague stressed the importance of finding an advisor and research collaborators who believe that women are equally as capable as men. This is a worthwhile tip for anyone in a minority group. If you have children or are planning to have children during graduate school, it would be a good idea to check into family services offered by your prospective schools, such as family housing and child care.

Also, seek the help of role models and mentors. I draw a distinction between role models and mentors in the following way. Role models are the people you idolize, the people who are in the place you would like to be in 10 years. Mentors are the people who can guide you to become who you want to be. Sometimes you

can find a role model and mentor in the same person. However, you will often have to seek out several people to fill these roles.

Lessons learned the hard way

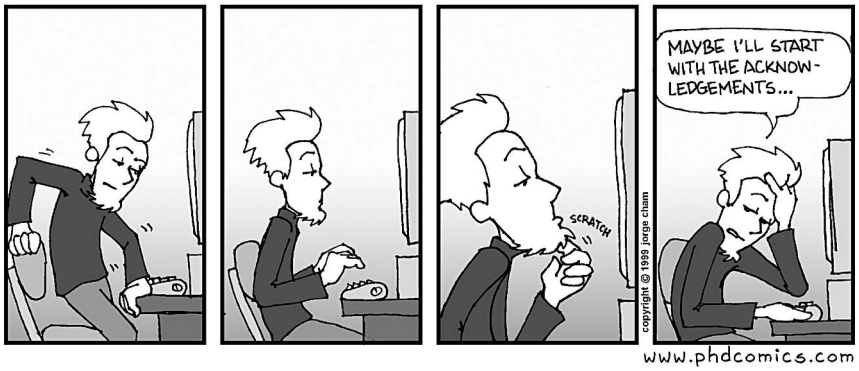
Business cards—You don't want to be the only person at a conference who has no contact information to share. Consider leaving the address and phone number off the cards. Graduate students can change offices several times during their graduate tenure. Instead, have a web site and e-mail address, which seldom change, printed on the card and post your mailing address and phone number on the web site, where they can be easily changed. Anyone you meet at a conference will likely contact you first via e-mail, anyway.

Web sites—Have one. They are the most convenient way to disseminate information about yourself. Put a your photograph of yourself on the web site. This will help people who want to meet you at a conference by letting them know what you look like in advance.

Data collection and display—This is a big one. As a scientist, engineer, or almost anyone trying to get a Ph.D., you are likely to handle a lot of data. If you collect and organize it properly, you will be prepared when you need to assemble it all for a conference, paper, or thesis. If you organize it poorly, you will cause yourself pain and suffering, waste time recollecting data, and possibly even cause doubt and confusion about your results. Here are some suggestions I wish I had from my first day of graduate school.

Start collecting data in a format you can process. For example, some measurement equipment will output data as a graphic file. It looks nice but renders individual data points essentially inaccessible. Whenever possible, collect data in the rawest format possible (i.e., numbers). You can always plot the raw data if necessary. Having data in a raw format allows you to replot it in another format (e.g., with different units), replot it along with another set of data, or process it in some useful fashion.

Plotting data very well is very important because graphs of data are frequently where insight is gained about your work. More than once I've heard my advisor say, "That sounds great. Now let me see the data!" Since plots are such an important part of any conference presentation or journal publication, they should be well designed. The axes should be clearly labeled in a large font. The salient aspects of the data should be emphasized (e.g., pointed to with arrows), and all your graphs should be produced with the same software, if possible, to maintain a professional appearance.



If you decide to plot all your data in the same fashion, you will need to select a single plotting program. This program should be versatile, capable of plotting linear and logarithmic graphs in several colors and styles, and have the ability to add text and change font sizes. You should be well versed in the program. If you are currently not familiar with a plotting program, don't panic. Most plotting programs can be learned well with just a few days of effort. Selecting a program that is commonly used is not necessary, but it can be helpful. Using a widespread piece of software increases the likelihood that you can share code with your colleagues. There are a number of good plotting programs, such as MATLAB, Gnuplot, and Origin. I use MATLAB because it is versatile, widespread, and I am comfortable with it. I have even made a MATLAB "cheat sheet" which includes minutiae I tend to forget, such as commands that assign datapoint color and type.

Besides the proper ways to collect data, I would be remiss if I didn't mention the other type of visual display: pictures. There are many different types of pictures in academic publications: photographs of an experimental setup, pictures of devices, schematic drawings, graphical results from simulations, etc. As with collecting data, a lot of time can be saved with taking pictures properly the first time. Time spent collecting quality images is time well spent. You may surprise yourself at how important a few good pictures can be for getting your message across.

The major recommendation for collecting pictures is to take them in high resolution. Some journals not only recommend it, they require it. You can always save them in a more condensed, lower quality format, but you cannot make the resolution better than your existing file. Also, if you need to zoom in on a particular feature, an image with marginal resolution will severely limit how much you can zoom. Images taken in .tiff format have large file sizes, but they also have a correspondingly high resolution. The images can be resaved as a more byte-friendly .jpg or .gif if a situation arises where this is necessary.

Also, I strongly recommend backing up your computer hard drive frequently. CDRs are well under US$1 each. The money spent on CDRs is money well spent when considering the alternative of losing a year, month, or even a week of work. I back up my hard drive at least once per month, as well as after every time I've collected a significant amount of data or written anything.

Writing—Writing technical papers and giving technical talks is the most feared and hated part of graduate school for some students, yet it is one of the most important. I have a story to illustrate this point:

I was sitting in a large lecture hall at a conference on the eastern coast of the United States. It was the middle of the afternoon, so I had already spent over four hours listening to technical talks. The current speaker had been talking for about 10 minutes, but the material was organized poorly, causing me to lose interest. To fill the time until the next talk, I decide to look up his written paper in the conference proceedings. Wow! His work was great, but I would have not known this had I not looked at his paper.

In this story, the student was saved by the fact that his paper was well written. Had the paper been of poor quality, I would have concluded that the work was of poor quality. He would

have improved his situation if his presentation had been as good as his paper. (I'm sure a large portion of the audience just tuned out instead of looking at his paper.) The basic point to remember is that, as a student, the primary purpose of your research is to expand the knowledge of your particular field. If you spend nine months doing excellent work and only three days on the writing, you probably won't effectively pass on the information to others. This defeats the purpose of published research, which is to share the things you learn.

Fear not, though! Even if you weren't born as good a writer as Mark Twain, all is not lost. There are many places you can seek help to improve your papers/presentations (make sure to seek help early!).:

1) Have your advisor and group mates read a preprint of your work. They are knowledgeable about your work and can help with technical content.

2) Have someone working in your field, but not in your specific area, read your paper. They can provide a fresh perspective and very valuable comments regarding the structure and flow of your paper (e.g., "You talk about the results two pages before you describe your measurement setup," or "you didn't provide enough details when you described how you built the device.").

3) Seek professional help (many schools have technical writing centers that can help you refine your work).

References—Any publication you submit to will require you to cite relevant, prior work by you and others in your field. It is not uncommon to have over 100 references in a Ph.D. dissertation. Organizing these references can seem like a daunting, almost overwhelming task. Thankfully, there is software that will store and organize these references for you, such as *EndNote, ProCite*, and *Reference Manager*. There are three major timesaving features of these reference programs.

1) Most word processing software will work with reference software to create a bibliography in any format. You tell the software which reference to cite and where to cite it, and the software automatically creates a numbered bibliography. You can even insert another reference in the middle of the paper, and the software will recreate and renumber your bibliography. We've come a long way from the days of typewriters and correction fluid!

2) Many online databases of academic material can now directly import the information into your reference database, saving you from having to manually enter all your references into the database. I recommend you start using this software *as early as possible* to avoid having to go back through your old papers and type in the references.

3) You can save .pdf files of the papers you cite and use the reference software to link the citation to the location of the file on your computer. This is *very useful* for times when you need to check an equation or statement from a paper you've cited. This is a lot easier than rummaging through a dusty file cabinet!

Acknowledgments—Don't overlook them. They are an important part of any publication. Acknowledgments are a painless and appropriate place to thank people for a contribution to your work. Things worthy of acknowledgment range from help fixing an experimental apparatus to telling you about a good reference you should read. The people around you will be very grateful when their help is acknowledged and possibly very hurt if it is ignored. So, be very generous with your acknowledgments. They don't cost a thing, and I'll bet that if you think about it ,you'll realize that a lot of people contribute to the success of your research.

Writing a thesis

Since I'm only in the early stages of the process, there is not much I can say. As with most tasks that involve writing, starting is by far the hardest part. I've always found editing my writing less stressful than writing something from scratch. To this end, any work you can publish in a conference or journal during your time at graduate school will pay dividends when it comes to thesis-writing time. You can paste these papers together, smooth over the rough edges, and fill in some details, which seems a lot easier than staring at a blank screen, faced with the gargantuan task of creating more than 100 pages of writing from nothing.

Conclusion

Of course, there is still a lot to figure out, but you wouldn't be going to graduate school if you didn't like to figure things out. So, work hard, enjoy your time, and roll with the punches.

Acknowledgments

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Read more about it

• K. Donaldson, *The Engineering Student Survival Guide*.

• Bloom, Karp, and Cohen, *The Ph.D. Process: A Student's Guide to Graduate School in the Sciences*.

Funding

• National Defense Science and Engineering Graduate Fellowships, http://www.asee.org/ndseg

• Hertz Foundation, http://www.hertz fndn.org

• National Science Foundation, http://www.ehr.nsf.gov/dge/programs/grf/

• http://www.finaid.org/otheraid/grad.phtml

Minority issues

• R. Felder, "Impostors everywhere," *Chem. Engr. Education*, vol. 22, no. 4, pp. 168–169, Fall 1988.

• Society of Women Engineers, http://www.swe.org

• National Society of Black Engineers, http://www.nsbe.org

• American Indian Council of Architects and Engineers, http://www.aicae.org

• Society of Hispanic Professional Engineers, http://www.shpe.org

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