Some Important Things Most Students Never Ask About Graduate School

Written by: Rob N. Candler

Illustrations by: Jorge Cham

Who Should Read This?

This article is intended for people who are considering going to graduate school or who are currently in the first year of graduate school. It is primarily focused on the decisions you will make on the path towards a Ph.D., but many of the same issues would certainly arise in a M.S. thesis-based program. The context of most of the discussion is an engineering program at a top research institution, but many of the comments would also apply at different level institutions as well as in science, medicine, and the humanities. This article is equally targeted toward all students in science and engineering, but there are certainly issues of representation, bias, and treatment that apply especially for students coming from underrepresented groups; I have drawn from conversations with students from these groups for these issues, but the issues raised here should be understood by everyone. Even though this article is intended for students, I hope that some faculty and advisors take the time to refresh their perspective on the "student side" of their relationships.

Why Did I Write this Article?

Because I had no idea what to expect when I started thinking about going to graduate school. Because some of the mistakes made by my friends or me were costly, and if I can help steer people away from some of these mistakes, that would be a good thing. There is some good information out there for undergrads[1] and graduate students[2], as well as some excellent information about teaching and academics in general[3], but I didn't know about any of it until I started writing this advice article, which was a little too late for me. I hope this material finds you earlier than it found me. Also, I wasn't able to find a whole lot of material about the everyday details of graduate school. So, I've included thoughts about the day-to-day challenges that occur in graduate school, with some anecdotes from friends and cartoons from the "PhD" Comic strip (www.phdcomics.com) to keep things interesting.

So, read and enjoy. I hope there are some answers to be found within. Even if all the answers are not included, I hope the following paragraphs generate many questions, because knowing the right question is the first step on the way to knowing the right answer.

[1] *The Engineering Student Survival Guide* by Krista Donaldson

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

[3] *http://www.ncsu.edu/felder-public/*

What is in this Article?

Included in this article are stories and lessons I've picked up along the way, some from my personal experience, and many others I have picked up from friends who are currently or have previously been in graduate school. Not all of the anecdotes I have collected are from people in technical fields (although the vast majority are). However, this article has a purposefully technical slant. Some of the topics discussed within are:

1 *Deciding whether or not graduate school is a good decision for you*
2 *Tips on selecting schools*
3 *Advice on choosing an advisor*
4 *Comments from engineers in underrepresented groups*
5 *Details about the nitty-gritty of a technical graduate program that can save you time and frustration (e.g. data collection techniques).*

A few caveats: this article is comprised primarily of my own experiences and anecdotal evidence from several people who have experienced graduate school. This assembly of stories is not an acceptable format for a scientific paper, because I will not show scores of plots with quantitative data in an effort to convince you of my ideas. Also, not every school does things in exactly the same way. Some schools may assign you an advisor upon admission, making parts of this article unnecessary for you, while other schools may require that you spend time with two or three different advisors to find a good fit. You will probably get the most out of this article by viewing it as a set of important concepts that you can adapt to your particular situation. However, since the information below is not accompanied by a robust statistical analysis, I offer it up to give you some things to think about as you progress toward and through graduate school. The decisions are ultimately up to you.

This is written from the perspective of someone well into the Ph.D. process (5th year Ph.D. student in electrical engineering). Is it possible that I'll change my tune in ten years after I've seen the other side of the faculty student relationship? Possibly. Is it possible that I'll become a faculty and regret sharing some of my secrets on advisor selection? Possibly, but I don't think so. The comments on advisor selection are aimed to provide a best fit between advisor and advisee, a win-win situation.

Before You Arrive At School

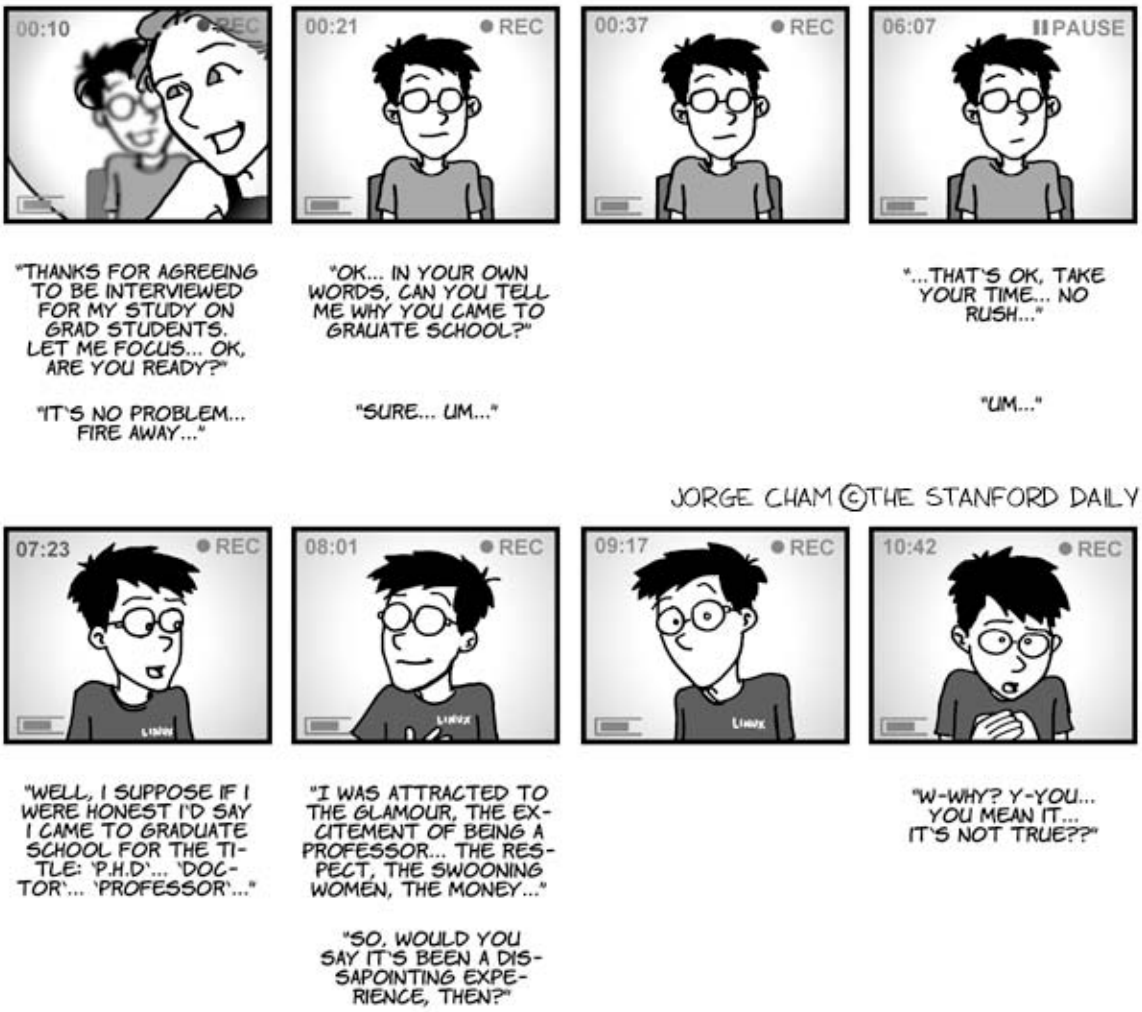
To go or not to go…

The first decision you should make before you arrive at school is, "Should I even go to graduate school?" To make this decision, you need to take a careful look at what is your motivation for going to graduate school. 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 these equations we had learned. A professor from my undergraduate years gave me a good analogy for this. He said that you're given a toolbox at the beginning of your undergraduate education. Each class you take gives you another tool to put in your toolbox. So, the question you're really asking yourself at graduation is "What do I do with all these tools?!?" Extending this toolbox analogy, 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.

A major portion of time getting an M.S. is spent acquiring new tools and using some of your existing ones. That is, you take advanced courses in areas of interest along with some project-based classes to gain the experience of solving a more involved problem than those involved in weekly problem sets. Also, some universities have the option (or requirement) of performing a research project and writing a thesis describing the work, allowing you to apply these tools to a project with greater depth. A Ph.D. involves coursework requirements similar to that of the M.S. and often may have some additional course requirements. The major distinction occurs with a Ph.D. dissertation. The Ph.D. dissertation is different from a Master thesis in that it is a more involved research project that should push the frontiers of knowledge in its chosen field. It should involve doing something that no one else has ever done before.

Common motivations for getting a M.S. include higher salary, a desire to specialize your skills, or maybe you were really interested in a class you took and wanted to learn more about that specific subject area. Common motivations for getting a Ph.D. also include a different set of tasks, commonly a more research-oriented environment as opposed to an environment more geared toward the development and manufacturing of products. Also, there are people who have been jokingly called *terminal students*. They love learning new things, and school, be it kindergarten, high school or a Ph.D. program, is a great place to learn 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 for jobs intended for someone with fewer degrees, and 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., because friends I know with a B.S. have used their general problem-solving skills to get all types of jobs including fields of engineering outside their major and consulting in a variety of fields.

A special subset of Ph.D.-enabled tasks is academia. Many people, including myself, would like to teach and research in an academic setting, which, for most technical fields, requires a Ph.D. A higher salary is not necessarily a good motivation for a Ph.D. Since getting a Ph.D. can take several years, 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 experiences can help you decide which of these careers and degrees are best for you.



Ok, so you're going to graduate school…

After deciding that you would like to go to graduate school, the next necessary step is to decide where to apply. Applications are generally due some time around December the year before you plan on starting school. Many people apply to 5 or 6 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 in the application process to prepare for early 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 1 month to those people who are writing you letters of recommendation.

The criteria for selecting a graduate school could certainly generate a heated debate. I will present views from a few friends who now have their Ph.D.s. I will also present my own opinion, and I'll leave it to you, the reader to decide what is important to you. When selecting to which graduate schools I should apply, I asked three trusted friends for their school selection methods, and I got three distinct answers. The first told me to go the most prestigious school to which I could get accepted. His reasoning was that graduating from a prestigious school would make the job search, especially a faculty job search, easier upon graduation. The second friend told me that if there was one particular person I wanted to

work for, I should go to that school. He also said that if there was not a particular person I wanted to work for, I should go to the best school into which I was accepted because it would be most likely to have someone I could work for. The final person said I should find an area where I would like to live and find a school there.

I have taken selected parts of the advice given to me by these three people to form my opinion. My opinion on selecting schools to which you should apply is a combination of the first and third pieces of advice above. 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 1-3 years, are generally less concerned about the school location as compared to people in a Ph.D. program, which can take 5-7 years. Contrary to the belief of some advisors, there is life outside the lab during graduate school. It is my opinion that a few enjoyable activities outside of your research may actually *increase* productivity, because you will generally have a more positive attitude, which could translate into a higher productivity rate while in the office and 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 that have had difficulty because of this. 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 selected a school for the same reason, but found out after his arrival that the advisor would be unable to obtain the necessary funds to sponsor him as a graduate student. Just because I'm advising against putting all of your eggs in one advisor's basket does not mean you shouldn't surf the web to see in what sort of subject areas a school is focused. It *is* important to make sure that the schools to which you apply have research being conducted in your area of interest. Ideally, you would be able to identify 2 or 3 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 are applying 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 didn't exactly become a millionaire as an undergrad, so you would like to find another way to get through graduate school besides going into massive financial debt. In other words, you need funding! 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 in a specific area, and **fellowships**, which are addressed below. Departments may help to set you up with one of these types of funding. You can also help yourself, using your skills to gain funding. For example, you may have taken several classes in a specific

subject in undergrad, making you a good candidate for a teaching assistantship in that area. Be aware that 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**, which 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[4]. 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, and 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 of whom you select as an advisor. Who could 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 have 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!

After You Arrive at School

Advisor selection

If you plan on doing research at your selected school, it is my strong belief that who you select as an advisor is *the most important decision* you make while at graduate school. One important 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*. To restate the previous sentence, finding a person with whom you can work well is more important, in my opinion (and the opinion of many people who have been in graduate school), than finding a person with what you think is the perfect project or a similar project to what you were working on in 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 does not have to be directly in your field of 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. Of course, check that your school allows interdepartmental advising before you plan on something like this. Most technical fields are changing rapidly enough that you would have a difficult (and probably boring) time making a career out of a single, very specific project. Not to say that it can't be done. Some people take on large and/or very difficult problems that take a lifetime or more to solve. However, it is my belief that a good number of scientists and engineers will encounter multiple

[4] National Defense Science and Engineering Graduate Fellowships (www.asee.org/ndseg), Hertz Foundation (www.hertzfndn.org), National Science Foundation (www.ehr.nsf.gov/dge/programs/grf/), www.finaid.org/otheraid/grad.phtml

projects/topics in a lifetime. Keeping a breadth of research is important not only for maintaining challenge and interest, but also to allow you to ride out years when one field is not especially well funded. This is somewhat similar to diversifying your stock portfolio.

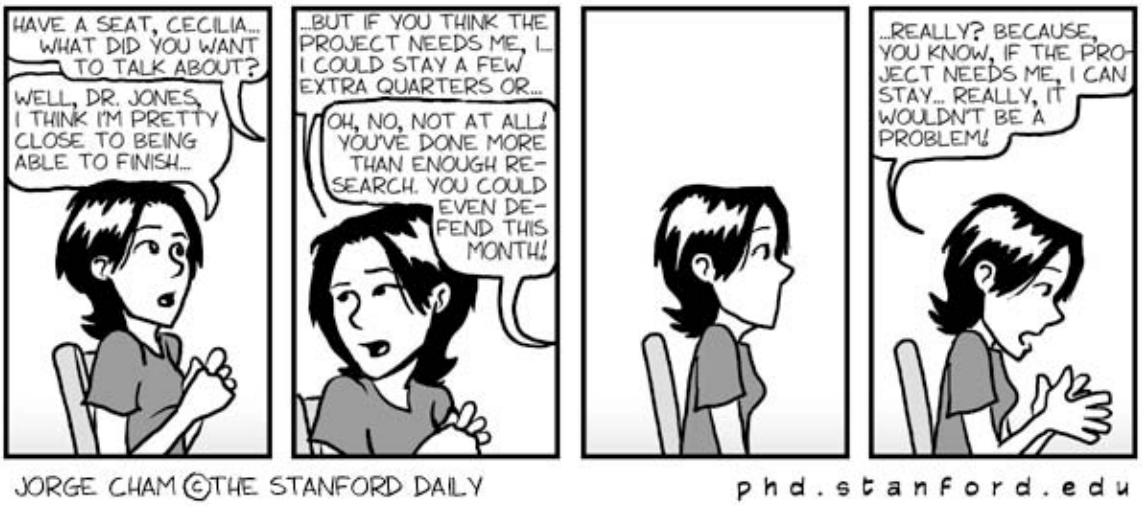
If you are at the point where you want to select an advisor and are faced with

several choices, you will likely 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 still work. However, since this is a matter of interpersonal relations, much of your data will be more qualitative than you are accustomed to. Nevertheless, the engineering mindset can be adapted to solve this problem. The things you need to consider to solve this problem 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 you can get in contact with, the advisor and some of his/her students. The questions you should ask I will discuss soon. Meeting with a potential advisor is probably best done in a formal setting, in the office of the advisor for example, because it is the most convenient for him/her. Meeting with the graduate students of a potential advisor would probably be the most useful to you if it were in a less formal setting. I recommend an off-campus meeting. Students are more likely to be candid if they are not sitting in their office, a few doors down from their advisor. Offering to take a graduate student to lunch has a high probability of success. Graduate students are rarely independently wealthy and are frequently hungry, so it is unlikely that the average graduate student would pass up a free meal. In fact, I once had four rooms of furniture moved for two large pizzas. I have 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. As far as what to ask him or her, (1) you can ask about current research projects. (2) You can get a feel about the level of funding an advisor may have for new students. (3) You will get some "face time" so the advisor is more likely to think of you when 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. You're still in school, and your primary purpose is to ask and answer interesting questions. Also, asking lots of questions will show the professor that you are motivated, smart, and interested.

As for a meeting with the students of an advisor, there are several important questions you can ask to get a general feel of how the advisor runs his/her group. One good piece of quantitative information you can collect 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).



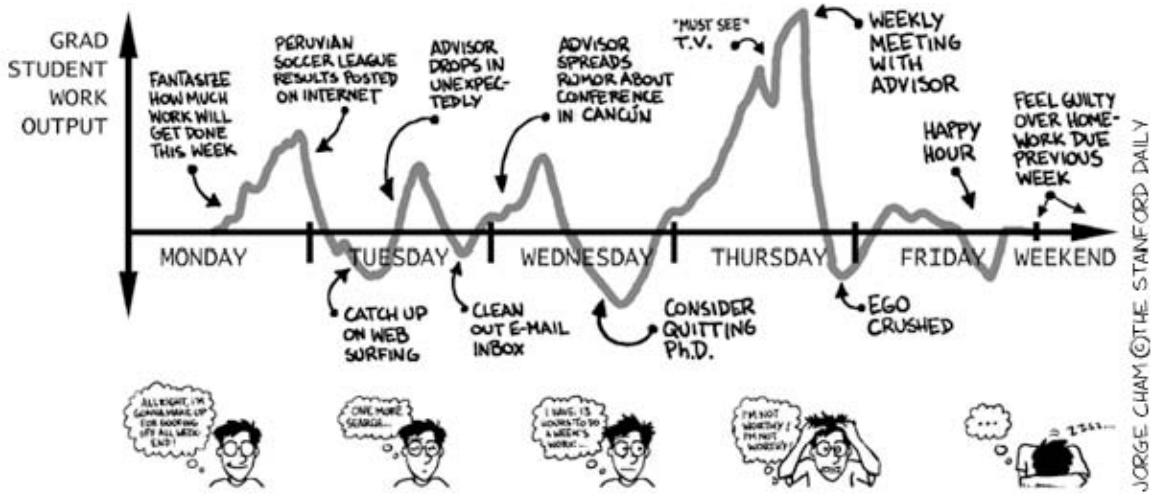
The amount of time an advisor spends with to his/her students is also something useful to ask. Advisors may have periodic group and/or individual meetings with their students. The period of time between these meetings is the number of interest to you, depending on whether your work style is interactive or independent. Personally, I'm interactive. I believe that bouncing your ideas off other people is a good way to get early feedback, allowing you to avoid time-consuming dead ends, as well as providing a fresh perspective for the times when your thinking is in a rut. So, ask the students how frequently they see their advisor and how available their advisor is when needed. Is he or she in the office regularly for questions? available via e-mail for questions? Also of interest to you is how the advisor gets funding for his/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 of academic conferences is a good thing, because 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.

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, so important that I've devoted a paragraph to it below. 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 to ask students in a research group 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 in support of these answers.

Different advisors have different management styles that range from involvement in day-to-day activities 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/her 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, and also so 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.

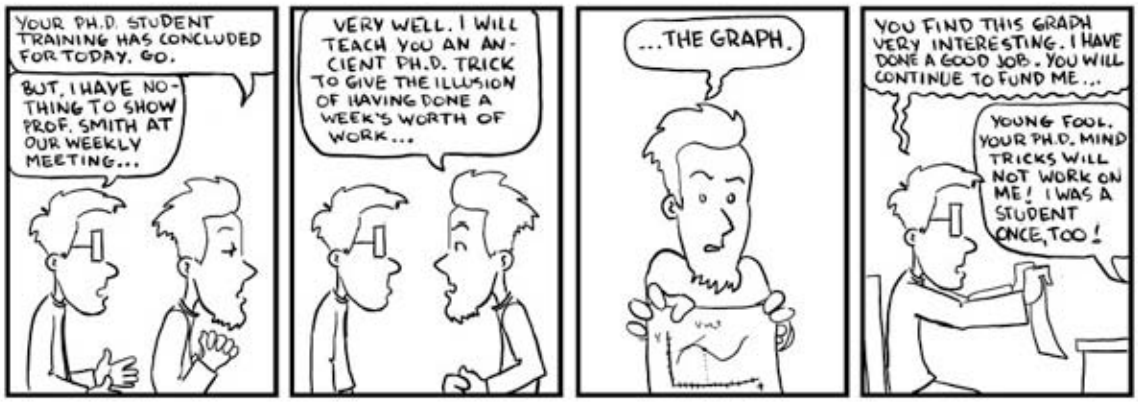
Don't be reluctant to "trust your gut feel." If you didn't enjoy the first meetings and don't look forward to the next one, this is an important clue; your relationship with your advisor will be tested along the way. Grad school is full of emotional peaks and valleys that occur when things sometimes go well and sometimes do not. You need to be comfortable with the person to deal with all the challenges that will come up.



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 and later realize that you have picked someone with whom you are completely incompatible, don't be afraid to change. It is a process that requires work and may set your graduation date back a bit, but you and your advisor will both be happier if there is a good working relationship.

Meeting with your advisor

Having a regular one-on-one meeting with your advisor is a good thing, if both of your schedules permit this. If this is not possible, running your ideas across one of your colleagues can be helpful as well. A regular meeting will help keep you going in the right direction with your research, and in doing so will reduce the time you could potentially waste on dead-end ideas. When you go to meet with your advisor, it is a good idea to have some sort of printout/handout that shows results from what you have been working on. This will show your advisor that you've been working on something. 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 visuals (imagine attending a class where the teacher wasn't allowed to write anything on the board or show any slides!).



Group mates

In a typical university setting, 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 a research group, and I refer to the people in this group 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 matter 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, seeing them on a daily basis. They are knowledgeable and current in your field, and they are readily available. Everyone will benefit if you can give constructive feedback on each other's work. Also, to stress a point made earlier, *it's alright to say you don't know something*. Asking questions is the way you learn about things you haven't heard about or don't understand. The less self-conscious you feel around your group mates, the more helpful everyone can be toward each other. So, don't be hesitant about interacting with your group mates. I've been told, "Don't be afraid to hang around the water cooler," which captures my observation that many of my best ideas have come from casual chatting with my group mates. Social interaction is a way to make work more enjoyable. Sharing an office with people is generally more enjoyable if you know and like them. Also, having a friendship with your workmates 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 too much control over whether or not you have collaboration with the industry, but here are some factors to consider. The quality of collaboration can vary, so there aren't any generalizations to be made. However, there are some possible pros and cons of which to be aware. 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 of an industrial collaboration that could be considered a pro or a con, depending on the circumstances and your personality. One of these aspects is the additional mentoring that can be as good as another wise mentor to provide guidance, or as bad as 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 some

people who believe the structured project limits their creativity. Another potential con of industrial collaboration is the restriction of publications that can occur. Information is valuable to companies, and they aren't always interested in giving away. Sometimes they will 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 publications early.

Issues that are especially for underrepresented groups in engineering (but still pertain to all of us!)

All the content from this section came from helpful discussions with engineering colleagues in underrepresented groups. However, after I wrote it, someone pointed out the information in this section could be useful to everyone, not just students in a minority. This section has two major components (1) some common feelings people from underrepresented groups may have and (2) things you can do to make your experience more enjoyable.

There are two phenomena that are common among minority students in engineering. The first is the "imposter syndrome[5]." It is basically feelings of self-doubt that manifest themselves in thoughts such as, "Do I really deserve to be here? I feel that everyone else is so much smarter than I am!" Actually, virtually all students have these feelings at some time during their school. They can result from general insecurity, the thought that you were admitted to fill some sort of quota, coming 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 have 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!

[5] Felder, Richard, "Impostors Everywhere." *Chem. Engr. Education, 22*(4), 168-169 (Fall 1988)

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 community. Just as establishing a good relationship with your group mates can make your experience as a graduate student more enjoyable and productive, finding a group of students with whom you can closely identify can be valuable. Seek these people out and talk with them. Fortunately, many of these groups already exist[6]. A female colleague stressed the importance of finding an advisor and research collaborators who believe that women have equal capabilities as men. This is a worthwhile tip for anyone in a minority group. An issue that is particular to women is that of children. 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.

Another way to better make your way through graduate school is to 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 who 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 what 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. Be aware that these people will not knock on your door and ask to mentor you; you have to seek them out and ask them to mentor you.

Details you would not think about until after they have happened

Following are several lessons I have learned by experience. Hopefully, you can take this information and avoid some of the hassles I could not:

Business cards – A good thing for any Ph.D. student to have. 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, and you don't want to reprint your business

[6] Society of Women Engineers (www.swe.org), National Society of Black Engineers (www.nsbe.org), American Indian Council of Architects and Engineers (www.aicae.org), Society of Hispanic Professional Engineers (www.shpe.org)

cards every time you move from one office to another. 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 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, which 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 along with another set of data, or process it in some useful fashion.

Plotting data is very important to do well, 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 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 data point color and type.

I've just written at length about proper ways to collect data and 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 by 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 if a publication or presentation requires, but you can not 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. There is really no reason not to save your images in some high resolution format. CD and DVD burners are ubiquitous, enabling you to store large amounts of images with little cost and hassle. USB memory sticks with capacity in the 100s MBs of storage capacity can be readily purchased for under $50. Also, on the topic of cheap, accessible memory storage, I strongly recommend backing up your computer hard drive frequently. CDRs are well under $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 4 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 the 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, because 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 9 months doing excellent work and only 3 days on the writing, you probably won't effectively pass on the information to others. This defeats the purpose of published research. 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 pre-print of your work. They are knowledgeable about your work and can help with technical content. (2) Have someone not working in your field but not in your specific area read your paper. They can provide a fresh perspective and very valuable comments regarding structure and flow of your paper (*e.g.* You talk about the results 2 pages before you describe your measurement setup? 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 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 seems to be a daunting, almost overwhelming task.

Thankfully there is software that will handle these references for you, such as EndNote ProCite and Reference Manager. I use Endnote, a program that stores and organizes the books and periodicals I may want to reference. There are three major timesaving features here: (1) Most word processing software will work with Endnote 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.

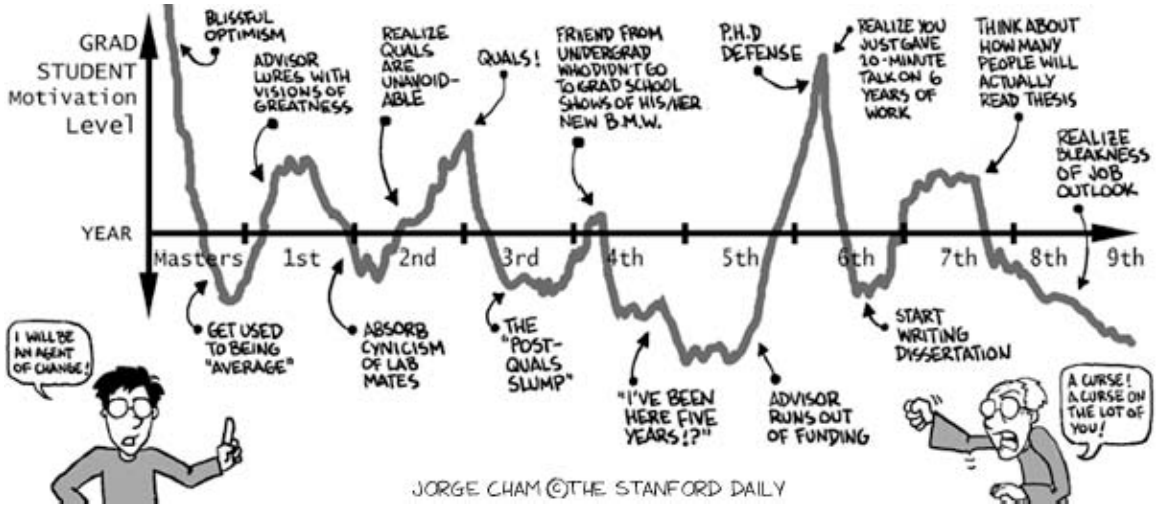
(3) You can save .pdf files of the papers you cite and use the reference software to link the citation to the location of the file on your computer. This is *very useful* for times when you need to check an equation or statement from a paper you've cited. This is a lot easier than rummaging through a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

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 > 100 pages of writing from nothing.

Conclusion

I sincerely hope that you have a few answers. More importantly, I hope you have a head full of questions. 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…



Acknowledgements

There is a large list of people in addition to the authors who contributed to the content given above. Thanks to John Owens, Lale Lovell, Bill Candler, and Bryan Smith for valuable opinions from the world after graduate school. Thanks to Jeffrey Li for his pre-graduate school perspective. Thanks to my advisor, Tom Kenny, for encouraging this venture. Many thanks to Tori Bailey, Jan Moolsintong, Amy Herr, Evelyn Wang, and Sumita Pennathur for assistance in writing, especially the section on issues faced by underrepresented groups. Finally, a special thanks to Jorge Cham (www.phdcomics.com) for allowing inclusion of his comic strips, which frequently offer more insight than any number of words could.