# AC 2010-572: TALES OF A 24TH GRADE NOTHING: A SURVIVOR'S GUIDE TO GRADUATE SCHOOL

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# Tales of a 24th Grade Nothing:
# A Survivor's Guide to Graduate School


## Abstract

Grad school is hard. The sheer volume of challenges that await new graduate students is staggering in number, ranging from initial decisions like "where to go?", "what to study?" and "who to work for?" to bigger questions such as "how do I get this to work?", "how can I learn all of this?" and "when am I going to get out of here?" Regardless of discipline and degree, the graduate school experience is comprised of a series of tribulations that are intended to strengthen and test the student, yet these same ordeals can also break the student. When I began graduate school in the fall of 2004, I truly had no idea what challenges and opportunities I would encounter over the next six years. My tenure as a grad student has been a whirlwind of classes, research, teaching, reading, writing, presenting, adversity, and fun. The lessons I learned along the way have helped to shape me both as a scientist and an educator; however I wish that I knew exactly what lay ahead during my graduate odyssey.

The goal of this paper is to provide that road map, both incoming and current graduate students, through a series of stories and lessons I learned during my graduate career. My goal is to provide fellow grad students with advice necessary to navigate the potentially tortuous path they will encounter such as taking classes, getting into the lab, working with an advisor, and publishing in addition to some more specific scenarios like teaching a course, landing a summer internship, and dealing with the cancellation of a research project. For each topic presented, I extrapolate valuable pieces of advice that have enriched my grad school experience in the context of personal stories and life lessons learned culminating with the opinion that although graduate school is hard, it is manageable and has the potential to be some of the most rewarding years of your life where you can learn and grow into the professional you want to be.


## Introduction

Similar to the pages of a "Choose Your Own Adventure" book for kids, the graduate school experience is a virtual cornucopia of decisions, opportunities, and experiences that mold a fresh undergraduate mind into someone called a master of science or a doctor of philosophy. Everyone begins grad school with a game plan, a series of tasks to complete and goals to overcome. However, these expectations often change as rapidly as the student as a results of new opportunities, experiences and, sometimes, even a complete paradigm shift of goals and opinions. For instance, I came to graduate school dead set to work for only one faculty member (who I didn't end up working for), graduating in four and a half years (I haven't), and leaving with at least five publications (I'm getting closer). As I navigated the tortuous path that is my own graduate career, I realize how I have made good choices and bad mistakes, learned lessons the easy way and the hard way, and grown as both a scientist and an educator. This series of events has led me to a point where I am finishing up my sixth year as a doctoral candidate, on the precipice of defending my thesis. As I look back over the journey I've taken, I wish that, along with my acceptance into graduate school, I had received a guidebook or detailed map with my thesis defense as the 'X' that marks the spot.

I want this paper to serve as that guidebook for future and current graduate students in the engineering field. I believe everyone reading this is quite capable of navigating his or her own graduate career successfully. My intent is only to provide some advice (and a few hints) on how to deal with pitfalls that appear during grad school, many of which can be very challenging to overcome. One of the most important lessons I have learned during my tenure in grad school is to take free advice from someone who has "been there and done that". I hope you, the reader, can learn at least one lesson that will help to streamline one aspect of your graduate career. Herein, I dissect some of the momentous elements of my graduate experience that relate to a specific event, such as choosing a graduate school, or are part of an on-going challenge, such as maintaining a successful and productive relationship with my advisor. Additionally, I feel it is important to include a disclaimer that the lessons and scenarios I present below are derived from my own experiences through my graduate program. Some of these may be different from what another person experiences during his or her years in grad school. If that is the case, I encourage you add your own stories and lessons to what I present. Ultimately, my goal is that this advice reaches and helps as many current and future graduate students as possible.

**Why I Attended Graduate School**

When I began my final year as a chemical engineering undergraduate, I had already decided that I wanted to go to graduate school and get my Ph.D. I had spent two previous summers in National Science Foundation (NSF) REU (Research Experience for Undergraduate) programs and developed a passion for conducting my own research projects. REU programs allow undergraduate students from different universities an opportunity to conduct a summer research project in collaboration with an actual graduate student. If you are an undergraduate (or teach undergraduates) who is interested in graduate school, I highly encourage you enroll in one of these programs -- it was one of the main reasons I choose to go to graduate school. The other reason I choose to attend grad school was my enthusiasm for teaching and my desire to teach at the university level (which I will discuss more later). I realize there are opportunities to teach and perform research in the industry setting; however, I did not find this to be the case when I was researching different jobs in industry and, therefore, cannot comment on the industrial experience.

After deciding that graduate school was for me, I had to choose a school. I took into account criteria such as rank, location, research topics, individual research groups, and an emphasis on instructor development. Eventually, I narrowed my choices down to six universities and sent out my applications. (On a side note, when sending out the applications, make sure that you choose reliable individuals for your letters of recommendation. I was waitlisted by a few schools because one of my letter writers never sent off my letter of recommendation, even though he told me he did). I recommend you apply to the schools for which you think you would be a competitive candidate, while not hesitating to *shoot for the stars*. Also, while it is a good idea to have a #1 choice, I advocate it is better to have groups or tiers of choices, so you are not disappointed in the scenario where you don't get your #1 choice. Getting into a few of your top tier schools, while maybe missing out on your #1 choice, can still make you feel good about the whole application process. Since I was not precisely sure what area of research I wanted to study, I selected a school that had the widest breath of topics with the most promising research. My selection was also strongly weighted by cordial and friendly atmosphere coupled with a

sincere sense of collaboration, another tenant I found desirable in my choice of grad school. This was not my first choice when I sent out my applications, but it ultimately ended up being the best fit for me. This is why I recommend that you *keep an open mind* when applying to and visiting potential schools because you never know what school will be the right one for you. Furthermore, when deciding to attend graduate school I highly encourage all new students to realized the commitment that lay ahead, with most thesis research involving many years of study, often working long days and longer weeks.

In the end, the most important piece of advice that I can give about choosing graduate school over an industry job is that you have to *really want* the MS or Ph.D. All of the members of my incoming graduate class who dropped out (without a degree) were people who only started grad school because (1) there was nothing better to do, (2) they did not know what they wanted to do with their lives, or (3) they couldn't find a job. Graduate school is not for the faint of heart or the uncommitted; however, if you do enroll, expect an exciting four to seven years where you will learn more "stuff" than you ever thought your brain could hold.

**The First Year**

My first year of graduate school was not exactly a "weed out" year, but it was a highly work intensive year encompassed by difficult classes and new teaching experiences culminating in my qualifying exam. Below I highlight just a few examples of challenges I faced during my first year in graduate school, but it is not a comprehensive list. Events such as how I handled my first semester as a teaching assistant or how I survived my qualifying exam were very important events; however, I decided to not include them to keep this paper from becoming a book.

The bulk of my first year was centered around taking a set of core chemical engineering courses that were similar to what I studied as an undergrad, except the degree of mathematical difficulty and the amount of information I was expected to absorb increased dramatically. This increased degree of difficult was compounded by the expectation to excel in my courses so I could begin work on my thesis. I do not have a secret formula for performing well in a graduate course beyond study, work hard, and start assignments early; however I found this was only half of what I needed to survive, I also needed to rely on my classmates for aid and advice. As engineers, teamwork is instilled in us at an early stage. From homework groups in sophomore classes, to lab groups, and finally to the senior design team, I have always found four minds are better than one, logic that transcended into my graduate classes. My first year class was comprised of 24 people of different backgrounds, strengths, and weaknesses. Faced with a common adversary, we stuck together and helped each other, from discussions about theory to aid on homework assignments, to advice on how and to handle difficult undergraduate students in the classes we TA'd. What I recommend to all first year graduate students is to *make friends with your classmates and stick together* like an army landing party. You are all faced with the same trials. Getting through them alive and sane becomes dramatically easier when you work together instead of trying to outperform each other.

Furthermore, this sense of camaraderie amongst my classmates helped make the advisor selection process almost painless. This process varies widely with some departments recruiting directly into a research advisor's group, while other departments expect all first year students to

do a brief rotation through each research group to find the best fit. At my university the advisor selection process is set up to maximize the preferred pairings between graduate student and principle investigator (PI). Halfway through the first semester, all of the grad students are encouraged to meet with anywhere from three to ten faculty members and discuss the student's interests and the faculty's expectations. After these meetings all of the graduate students write down their top three choices for research advisor and submit them to the faculty, who then convene and discuss student and advisor pairings. The rubric for advisor selection worked very well for my class because we all met prior to the submission date to discuss who wanted which advisor with the atmosphere in the room similar to an amiable NFL draft selection. Because we were so close from having worked together in core classes, any potential conflicts were resolved at this meeting instead of having individuals get stuck working for faculty whose research interests did not coincide with their own. In fact, I actually gave up my first choice of advisor to another student who was more passionate about working for that particular advisor. I do not recommend this tactic for most students during the advisor selection process, but I did not regret this decision because I had strong interest in my second choice, an advisor with exciting biomolecular engineering research. Regrettably, I have seen subsequent classes (who do not get along so well) try to work the advisor selection process like a hand of blackjack, with disastrous results.

Here are a few tips for selecting a research advisor. First, meet with your top advisor choice and express your interest from the start. These initial meetings are very important in the advisor selection process. You are making a choice to work very closely with someone for the next four to six years on a specific research topic. *Make sure to ask all of the questions* that are important to you, such as average number of publications per student, expected work hours, post-graduate destinations of previous students in the group, and more. It is better to know what lies ahead and what expectations are coming than to pick an advisor based on a few anecdotal pieces of information. In addition, *don't hesitate to demonstrate the initiative* like attending a few group meetings or shadowing a current group member when they run an experiment. This shows you what to expect from working in the lab and shows the advisor that you mean business about your choice. Second, *discuss your top choice with your classmates* and potential "competitors" -- other graduate students who might have an interest in the same advisor. Like any conflict, initial communication can help to prevent problems and hard feelings by establishing your expectations from the start. Finally, always have a back up plan. No one can predict how this process will end up working out, and it cannot hurt to have a good "second choice" advisor selection ready in case your first choice falls through.

**Stand Back, I'm About to Try Science!**

What many people do not realize about graduate school is that after the second year, you are essentially finished taking classes and solely focus on the research related to your thesis topic. There is the occasional seminar or course that is related to your thesis, but for the most part you tend to live in the lab or office. The acquisition of data is the ultimate basis of the thesis, but the functionality of specific pieces of equipment can be of more importance than your own health. As with previous sections, this is not an all encompassing list of how to plan and implement successful experiments, but rather a few life lessons learned while working in the lab over the past six years.

Depending on age, interest, and previous experience, entering the lab for the first time can vary from just one more place to work, to a completely eye-opening and frightening experience. When I started, I had previous lab experience but had never worked in a lab specifically designed for the study of mammalian cells using a novel microscopy system. As such, I felt like I was thrown into the deep end of the pool, having to learn new techniques and how to use new pieces of equipment that were critical to my research and, as a result, I spent my first summer in the lab walking around on egg shells. I was so petrified that I might break something , I did not accomplish much of anything. This brings me to my first lesson: *don't be afraid screw up*. In fact, it's a good bet that you *are* going to screw something up. Eventually you *are* going to end up with a failed experiment. And there is almost a 90% chance that you *will* break an essential piece of lab equipment. This does not mean you should expedite the process and go tearing through the lab like the Tasmanian Devil, but you should not be afraid to try a new technique or slightly deviate from an experimental protocol to see what happens. As Einstein famously said "If we knew what we were looking for, it wouldn't be called research." *Do not be afraid branch out* and attempt something ground breaking because you are worried that it will not work or that you will break things. Your mistake could be the most exciting part of your thesis.

Once I got comfortable and started building my confidence in the basic laboratory techniques required for my project I encountered a new source of frustration. As my project continued to evolve and new ideas were proposed, my required list of tools increased as well. It was very frustrating to have to learn how to use new equipment and build new tools for the lab that were outside of my comfort zone. It was equally frustrating to find labs on campus with the equipment or facilities required to build my new tools (in my case, the design and fabrication of a PDMS microfluidics device). However, looking back, I can say the rewards greatly outweighed my initial frustration. One of the pitfalls that you can fall into is the trap of complacency. I have seen colleagues who, after mastering a technique, essentially become a hammer looking for a nail. This method can work for a brief time, but in the long run (and especially in the hunt for a job or postdoctoral position) this severely limits your potential. I believe one of my greatest strengths is the number and variety of different experimental techniques I have learned during the course of my thesis work. This increases not only my theoretical knowledge but also provides me with multiple tools. I said it previously, but feel it is important to mention it again, *do not be afraid to branch out*. Take a deep breath and break out of the mold to learn as many new methods as possible during your graduate career. You never know what skill will help you get your next job.

In spite of all of the confidence you can gain in the lab, research can still be a fickle entity that can bestow great success but also impale you with devastating failure. I learned this lesson during the course of some experiments while trying to use a microfluidics device to study directed cell migration. Everything I had read in the literature suggested that these devices would be "foolproof", and an easy tool to accomplish one of the primary objectives of my thesis. After eighteen months of experimental design and data acquisition and multiple adjustments to my protocols and devices, I was still left with what I deemed a failure. My conclusion was verified by my PI, and we eventually decided to change directions and utilize another tool to prove my objective. Needless to say, I was frustrated by the failure of my supposedly infallible tool and disappointed that I didn't have anything to publish. But this was not the end of the story.

After closer examination of my data and some very useful recent publications, I discovered that all my work was *not* in vain. I was able to adjust my perspective and analyze the data from a different point of view and, somewhat magically, it did show something, even if it was not what I had expected. Currently I'm in the process of writing a paper based on the experiments I had abandoned six months previously. The moral of the story and the lesson that all graduate students (and some PIs) need to learn and be reminded of from time to time is *even negative results can be useful*. In research, there are very few times where *nothing* can be concluded from an extensive set of experiments. I recommend that you never give up on your data until you have looked at it from every possible angle to see exactly what you can extract from it (by force if necessary).

**The Advisor-Student Relationship**

The dynamic between a graduate student and his or her advisor is one of the most challenging relationships in all of graduate school. The most successful coupling can lead to an extraordinary and rewarding graduate experience highlighted by numerous first-author publications, while a dysfunctional one can lead to many frustrating and disappointing years and often culminates in the premature departure of the graduate student. I have had a multifaceted relationship with my thesis advisor, punctuated by exciting research and publications while sometimes plagued by failure and disappointment. What I hope to accomplish in this section is not to commiserate over whom has the worst advisor stories, but to impart a message of hope -- no matter what issues arise, both parties benefit by finding a way overcome them. This is not an encompassing guide of how to have the best relationship with your advisor, but rather a few lessons I learned from the mistakes I made dealing with my own advisor.

When I joined my research group, I made quite possibly the biggest mistake any new student could commit -- I hid. After my initial meeting with my advisor, I not only sat around and waited for him to come to me with tasks, but I did everything in my power to avoid contact with him to minimize the possibility of me looking stupid in front of him. I would ask senior graduate students for tasks to do, or sit and stare at papers for hours on end, with no real idea of the purpose of my thesis nor what the focus of my research should be. This went on for two years. This course of action came back to haunt me when I started working on my preliminary dissertation. What I know now, and did not understand back then, is every boss has his or her own style. I needed to find a way to adjust how *I* worked and approached problems to coincide with how my advisor handled them. Instead of just waiting and worrying about looking foolish, I should have approached my advisor and asked him the hundred questions I had rolling around in my head. What I recommend to new members who join our group, as well as any other graduate student who has advisor problems, is *just go and talk to them about it*. Ask your advisor about their thoughts on the project. Find out what their expectations are for your time in the office and lab. Utilize their wealth of knowledge and experience instead of worrying, trying to look smart in front of them (or trying to avoid looking stupid). I would have saved myself a great deal of stress an anxiety if I did this from the start.

Don't get me wrong, there will be those times where all you want to do is scream and bash your head against the wall. This happened to me when my advisor cancelled my first project (involving the quantification of proteins in an immune cell line) after two years, without any

possibility for a publication of my work. When we sat down to discuss my most recent round of (failed) experiments, he decided the project just was not going to bear any fruit and we should change direction while there was still time. All the work I had invested and our plans about what to change were unimportant now -- we just needed to stop and change directions. I was furious about this decision and spent a fair bit of time stomping around the lab and complaining to anyone who would listen. What I know now is *this is sometimes how research goes*. The failure of my project wasn't a personal reflection on my character or my intelligence. Whether in industry or academia, sometimes projects just fail and time and work invested go unrewarded. Ultimately, *I just had to get over it and move forward*. Getting angry about it will only taint your view of research, your advisor, and your graduate school experience as well as negatively affect your health. Once I accepted this fact, I was able to move forward on a new project with a renewed vigor and was ultimately able to produce some good, publishable data.

There will be good days, and there will be bad days. There will be times of happiness and success, and there will be times of disappointment and failure. There will be times when a meeting goes so well that all you can think about is that next round of experiments you need to do to prove your hypothesis. And there will be times where a complete lack of communication causes a great deal of tension and anxiety. However, in the end, the relationship between the student and the advisor should be a symbiotic one. My success, my publications and my presentations also belong to my advisor. My success is his or her success.

**Wait. . . . .I'm Supposed to Have a Personal Life?**

Yes, yes you are. We all need a break. Whether you are in graduate school, medical school, law school or have a "real" job, you need to take a little time for yourself. Most graduate students inherit or absorb an ability to feel guilty about relaxation and fun. *Ensuring that you have a personal life is probably the most important aspect of grad school*. Taking time for myself and relaxing is how I have been able to stay focused during my experiments, data analysis, and even writing. Stepping away and doing something fun gives me new perspective on a problem I'm working on. It gives me a fresh set of eyes when I'm staring at a blank computer screen trying to figure out what to do next. Since I started graduate school, I have gotten engaged and married (to the same person), gotten a dog, learned how to play golf, built a bean bag toss board, played in multiple soccer leagues, bought a car, read all the Harry Potter books, and traveled to China, Jamaica, Florida, California, and Washington, DC. Besides acknowledging your right to have a personal life, the biggest challenge may be how to maintain this budding personal life on a graduate student stipend. There are many different ways to have good, cheap fun, but I highly encourage you to find something to do outside of the lab that you enjoy to take your mind off of work. And, worst case scenario, you can always stock up on free food at the weekly departmental seminar.

The real key to surviving graduate school is to *maintain equilibrium between school work and your personal life*, and to do so in a way that works for you. I have seen this balance achieved in many different ways, from flexible work hours to setting personal deadlines and sticking to them. I have found that what works best for me is to give myself a "weekend" even if it is a moving concept. Sometimes I may have to work weekends or nights due to equipment availability, but I always try to give myself two days off during the seven day week where I can take time to rest,

relax, and get mentally prepared for upcoming week. Finally, I discovered that sharing my free time with other graduate students tends to ease the guilt that we all experience for not being in the lab. Because, let's face it, if your lab mate isn't working, then should you really feel bad about not working too?

**Graduate School is Like a Box of Chocolates**

What I have presented to this point are trials most graduate students will likely experience at some point during their tenure in graduate school. What I want to discuss now are a few additional opportunities I had during my years as a grad student. As I previously stated, the graduate school experience is mostly what you make of it. Some individuals focus solely on their projects to get out as soon as possible, while others choose to take advantage of other opportunities offered by their advisor, department, or university. I highly recommend that you *broaden your horizons* and participate in at least one of these additional programs. Looking back, they have been among my most rewarding experiences while in graduate school.

During the spring of 2007 my department had a shortage of faculty available to teach the core undergraduate courses, and, as a result, I was asked to teach a sophomore level chemical engineering course. One of the reasons I choose to attend graduate school was for my interest in teaching, so this was the best opportunity I could have asked for -- a chance to teach a class of sixty students and manage two TAs and four undergraduate graders. I was very familiar with the course, having served as a TA three times previously in addition to being a private tutor in this subject, so I felt confident saying yes to the challenge. However, even with all of my previous experience, being a responsible instructor was an overwhelming task for which I was not quite prepared. I naively thought I could step in and run the course with no problems because of all of my previous experience. This turned out to be harder than I anticipated. I encountered many of the typical problems of new faculty during their first semester teaching: I assigned too much homework, wrote an exam that was so difficult, I almost broke the spirit of my entire class, and, in the end, got frustrated at my students for not understanding concepts I taught poorly. Another aspect I did not account for in my eagerness to teach was how to maintain my duties as a research assistant and, more importantly to my advisor, make time to conduct experiments and continue progressing my thesis work. The time commitment of being a full time graduate student while teaching a class was astronomical. I constantly found myself falling behind in one arena or another. Even with all of the mistakes I made during this semester, it was probably the best (and most difficult) learning experiences. I learned a great deal about myself and my own limitations as an instructor. I also discovered the single most important aspect of being an instructor -- *never stop learning and never stop trying*. Based on my experience, I would caution any graduate student considering teaching a course by themselves to carefully consider the cost. However, I strongly recommend if you have aspirations of becoming a faculty member, *become more involved in undergraduate or graduate instruction*. Don't limit yourself to grading papers and holding office hours -- try writing and delivering a lecture or attempt to write an exam (a task that is much more difficult than I previously imagined). Teaching is a skill that you have to learn by doing. It takes many attempts and mistakes to find the style that works for you.

In addition to teaching, I was lucky enough to experience the type of science performed at an industrial research complex. As a part of a National Institute of Health (NIH) fellowship, I was

required to perform an industrial rotation; a ten week summer internship at a company specializing in biotechnology. With my advisor's help, I was able to obtain a position working for a top five pharmaceutical company conducting exciting, novel research. It was a great opportunity to see how research is conducted in industry versus academia; especially how the industrial focus is much more directly related to commercial applications than the strong theoretical basis driving most academic research. This internship was also a great opportunity to force myself to learn a new experimental system. It gave me a fresh start and a chance to redeem myself from previous mistakes I had made when approaching a new project. In fact, I returned from this internship with renewed vigor towards my own research project. I strongly recommend you take advantage of an opportunity like this if available and relevant to your work. You will gain a completely different perspective to help you decide if you want to continue in academia or move into industry.

**Publications and Presentations**

Although it is a cliché, "publish or perish" does seem to be the unspoken motto of most successful universities, even if no one wants to admit it. Beyond the desire to study exciting new topics, one of your goals should include *writing as many first author papers as possible*. Your success at meeting this requirement varies strongly based on the type of advisor and project. Some graduate students write one paper a year for three years and convert them into eventual thesis chapters, while others wait until the last four months of their dissertation to write three thesis chapters and convert them into publications after the defense. I am a member of the latter group, as is the case with many engineers who work in bio-related fields. I wish I could provide an inspiring story about overcoming procrastination and how I was able to write three high impact papers; but I am still in the process of writing them, so I guess you'll have to wait for the sequel to this paper. In tandem with writing, it is expected you attend conferences to present your newest and most exciting findings (or let your advisor do it). I have had the opportunity to attend a few conferences and found them to be exciting experiences in which I try to jam ten journals worth of results into my head over the course of a few days. I highly recommend you *attend at least one conference* during your time in graduate school, not only as an opportunity to learn, but as a venue for making contacts for possible collaboration or future employment. My current set of experiments is a result of a discussion that my advisor had with a colleague during a conference this past summer.

In addition to your thesis research, I believe it is import to conduct additional research that is of high personal interest, even if it does not directly relate to the thesis. As I said previously, one of my reasons for choosing a graduate school was my interest in teaching and engineering education. Apart from my thesis research, I have had the distinct pleasure to work with some great teaching faculty at my university, participate in educational scholarship and present and publish this work (mostly "on the side") while in graduate school. I know I have preached about the importance of having a personal life and taking time for yourself away from your research, but I found a loophole to this logic. If your extra work is something for which you are truly passionate and really enjoy doing, then it really isn't "work" but rather a nice break from what your stare at on a day to day basis. You may even find that your "side" interests turn into your primary interest, should the opportunity arise.

**"Here We Are, at the End of All Things. . . ."**

As Samwise Gamgee told Frodo Baggins at they ascended the steps of Mount Doom to destroy the one ring, here I am at the end of my journey. It has not been an easy voyage, but it has been an exciting one, especially since I submitted the abstract and began writing this paper. In the past six months I have had my share of disappointments: I lost my funding, changed the direction of my project, and spent weeks unsuccessfully looking for a post doctoral or industry position. Conversely, I have also had my share of successes, most of them taking place in the past few weeks: I have found a new source of funding (that will last until after I defend my thesis), discovered an exciting positive development in my research, and accepted an exciting postdoctoral research position. Ultimately, this is exactly how graduate schools works and the underlying message of this paper. *Graduate school is hard, but it is not impossible*. For me, it has been six of the most exciting and eventful years of my life so far. It has taught me the most valuable lesson that I would like to impart upon you, my faithful reader: *if I survive getting my Ph.D., I can survive anything*.