

## Success in Graduate Student Research

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*I am giving you these guidelines because you currently work with me as a graduate student researcher, or have expressed an interest in doing so. Please read this document carefully and let me know if anything is unclear or if you have questions. In the event we work together, I will assume that you understand this guidance and will always do your best to follow it.*

*As a rule, I will not consider serving as a graduate student's advisor until you have written a high quality paper for me that demonstrates your future promise as a researcher. This could be as part of one of my courses, an independent study, or a short-term research project. It is important that you understand what I mean by "high quality" and "future promise" – that is one goal of this document.*

Performing original research is an exhilarating experience. You have an opportunity to examine basic questions facing society that can be addressed through new ideas in computer science and engineering. You will become an international expert in a particular area. Others will seek out your advice on important topics. In the process, not only will you learn a great deal, but you will also have a chance to make the world a better place. With this opportunity comes significant responsibility, however. The purpose of this document is to explain my expectations if you work with me as a graduate student researcher, to offer advice that I hope is helpful, and to outline some of the things you should keep in mind to increase your chances of having a successful and rewarding experience.

While these guidelines reflect my own personal philosophies, you will find that other professors share many of these same attitudes. If you are working with another professor and are uncertain whether my advice applies in that case, please be sure to check with that professor.

Keep in mind that what I say here is meant to guide you, not to discourage you. Becoming a good researcher means learning many new skills as well as continuing to develop existing ones. It is important to know what to work on so that you can focus your energies effectively, and that is the purpose of this document. As with anything you do in life, making progress takes time and effort. There will be challenging hurdles to overcome. At the same time you start to pursue graduate studies, you must also be willing to recognize that research is not the right career path for everyone; if you discover this is the case, it is best to be honest and find a way to move on with alternate plans. Continuing to struggle in a situation where you do not excel will only lead to frustration and unhappiness. Remember there are many possible paths to success in life.

## **1. Motivation and Dedication**

An important underlying assumption is that you are attending graduate school – and that you wish to work with me – because you are dedicated to a future career where research and scholarship will play a central role. This could be serving on the faculty at a research university (like Lehigh), or at least at a school where the quality of your scholarship is an important criterion for advancement. It could also be a career in an industrial or government research lab. If your primary reason for attending graduate school is because you are a good student and enjoy taking classes, or you failed to get a job out of college, or as a way to “kill time,” then it is unlikely you will have the dedication to succeed in research. While any student may enroll in the courses I teach, when it comes to serving in a formal relationship as an advisor, I only mentor graduate students who are planning a career in research. This is a choice that lies deep within you, but professors can detect ulterior motives and lack of dedication.

This is also a good time to mention two overriding considerations that you should always keep in mind: scientific integrity and respect for your advisor's time. It goes without saying that I expect my students to uphold the highest standards of scientific integrity. Any violation of these generally accepted principals (e.g., falsification of data, plagiarism) will result in my dropping you as an advisee. You may also lose your financial support or be expelled from Lehigh. This applies to all of the work you do at Lehigh, including your coursework, not just the research you do with me.

Not demonstrating respect for my time is another serious issue. My primary goal is to advance science, and your role is to help me. In reading this document, you will see that there are certain things I expect a graduate student to be able to do. Professors are very busy people with many responsibilities. Successful graduate students take the initiative to learn the answers to basic questions on their own, without pulling their advisor away from more important work. Learn to tell when the help you are requesting is reasonable and when it is not – the signs will be clear if you pay attention. I may answer a question by saying, for example, “You should be able to figure this out on your own.” If you find you are making large demands on my time for issues that are not related to research, then you are not helping the research effort, you are hurting it. This should be a consideration you take very seriously.

## **2. Research is Different from Coursework**

It is easy to underestimate the significance of this distinction. You may believe that, because you are a student and I am a professor, performing research under my direction must be like taking a course from me – that it is my job to spend as much time as necessary helping you understand every aspect of the material under study. This is not true. Coursework is guided step-by-step by the professor, with the student doing the assigned work and adhering to a schedule the professor sets. If you do all the work and do it well, you can expect to receive an “A” in the course.

Research requires a level of maturity and initiative that goes far beyond this. You will find that I make few explicit demands of you. I will not even insist that you meet with me. This does not mean, however, that I do not have high expectations. I expect that you will take charge of your own research, that you will drive the work forward, and that you will ask to meet with me because you have discovered something interesting, encountered a problem and need some help, want some advice, or would just like to touch base and update me on your progress. When I think you are doing a good job, I will say so. If you do not hear me complain about your work, it does not mean your research is progressing well. This is a case where silence is not “golden;” rather, it probably means that your research is in trouble.

Thinking about it another way, your coursework, while important to you personally, will not change the

world. Research should aim at having an impact. It goes without saying, then, that your research deserves significant attention and all of the time and energy you would devote to a full time job, at the same time you may have other responsibilities like taking courses. (Graduate students work hard, but professors work even harder.)

Also keep in mind that being an “A” student does not guarantee success in research. Experience has taught me that some students can find a way to get good grades in courses, often by echoing back material they find on the Internet, but that they do not truly understand. If you fail to develop a deep understanding of our research topic, it will soon become obvious. Remember, you are supposed to demonstrate signs of becoming an expert in the area we are studying.

### **3. Claiming Ownership of Your Research**

It is not sufficient for you to treat your research like a job you are doing for me, even if I give you an idea that comes from one of my projects and I provide you with funding. I expect you to claim ownership of your research topic. If you take on a task only because I tell you to do it – if you regard it as simply a “job” to be completed as quickly and with as little effort as possible – then you will never become a successful researcher. You should take on a task because you find the question interesting and the work challenging and you believe it is the right thing to do to push your research forward. You must be passionate about your research.

Often, I will provide you with initial “seed” – an idea that I believe can be developed into successful research. Some ideas are more promising than others. It takes years of experience to develop this intuition – this is one of the skills you should strive to learn by watching your professors. While your success or failure will depend largely on your own ingenuity and level of effort, sometimes the idea I give you is one I am particularly fond of. It may be an important piece of a project we have underway. You will sense a growing annoyance in me if you fumble an idea like this. A good researcher overcomes hurdles and will let nothing stand in the way of getting the job done. It is a particularly bad sign if I must take an idea away from you because you fail to make progress and give it to another student or, even worse, if I find it necessary to go off and solve the problem myself because the project depends on it. Then you can be certain I am unhappy. Missed deadlines are not acceptable and another indication of serious problems. When I give you part of a project to work on, your primary goal is making sure it moves forward.

### **4. Interacting with Your Professor**

As a simple measure, if you find that you are not regularly scheduling meetings with me to discuss your progress – always with something interesting to report – then your research may be in trouble. Keep in mind that “regular” can have different meanings depending on the student. A student working on an independent study that lasts one semester should probably plan on meeting with me every week or two to stay on track. This is also true for a student just starting to explore a new research area. An advanced Ph.D. student who has already published quality research results and is working on the final stages of a dissertation might be able to meet with me less frequently – say, once a month.

In general, I find that better students ask to meet with me more often. Of course, if you request a meeting, you should have something worth discussing: an important insight, some new experimental results to talk about, a relevant paper you discovered, a hurdle you would like help with, etc. Suffice to say that if you schedule a meeting with me and have nothing to say or, worse, you miss the meeting, my

reaction will not be favorable. Do not waste my time. Keep in mind that if I am providing you with financial support, then I am paying you to help me advance research – I am not paying you to ask me basic questions that you should be able to answer on your own.

When you send me a draft of a paper to read, make certain that it reflects your best possible effort. Do not waste my time by sending me a paper that you know still contains mistakes or is very rough. Also keep in mind that my schedule is busy: never send me a draft right before the deadline when it is due. There is a good chance I will not have time to look at it at that point.

I expect all of the students who work with me to have certain background knowledge and skills. This is mostly undergraduate-level material and, if you lack it, it is your responsibility to make it up:

- You should be able to program and debug efficiently (at the level of CSE 411).
- You should be able to do high quality background research (literature searches).
- You should understand the design and analysis of computer algorithms (at the level of CSE 340).
- You should be able to use basic productivity tools like Microsoft Excel, PowerPoint, etc.
- You should be able to write a good paper using LaTeX (I dislike MS Word for technical writing).
- You should be able to prepare and deliver a good technical talk.

If you need too much of my help with any of these things, it may be a sign that you do not belong in graduate school. Successful graduate students learn to make up deficiencies on their own.

You will probably find that I send you email from time-to-time with information relating to your work. This could include pointers to newspaper articles, technical papers I think you should read, conference announcements in the area where we are working, etc. As a rule, if I send you an email, I expect a response; not necessarily right away, but certainly after you have had some time to think about it. Do not ignore what I tell you. Likewise, if you find something relating to our research and you believe it would be good for me to know about it, you should send me email, too. I very much appreciate receiving such messages and consider it a positive sign that you are invested in your research.

It is okay to disagree with me on a technical point – I make mistakes, too. But in such cases, be ready to support your position with strong scientific evidence. Make sure it is good: simply repeating the same unsupported claim over and over is not “strong evidence” – it is just wasting my time. Prolonging an argument with me because you think you can change my mind is generally a bad strategy.

One subject never open to debate is the level of work necessary for an acceptable dissertation. Earning a Ph.D. requires making a significant contribution to the field. Graduate students do not have the perspective to know what qualifies as “significant;” this determination falls entirely within the realm of the advisor. By itself, the fact that you believe you have done a lot of work means nothing. When you receive direction from me, you should give it serious consideration and, in nearly every case, act on it. I pay close attention to how students respond to my feedback. I do not expect you to get everything right on the first try, but you should be getting close by the second.

You may feel like you are operating on a tight schedule to obtain your Ph.D. Perhaps you have a scholarship that will expire, or a pending job offer, or maybe your family expects you to finish your degree within a specified timeframe. Know that such constraints have absolutely no impact on the amount of work that needs to be done for an acceptable Ph.D. If you try to argue with me that I should be willing to accept less work from you for such reasons, I will tell you to find another dissertation advisor. If you have time constraints, it is entirely your own responsibility to manage them – my standards are not negotiable and I will not lower them, so you should not even bother to ask.

## **5. Contributing to an International Research Community**

Ultimately, an important measure of the research you do is whether it is interesting to outside experts working in the field, not just to you, me, and other people at Lehigh. Our purpose as researchers is to broaden knowledge – to make a contribution that our most experienced, talented colleagues consider useful and important. You should be aware that at the same time we are working on a problem together, there is an international research community working on the same kinds of problems. Your goal is to gain acceptance into this community by becoming known as a researcher with original insights who does high quality work. Their evaluation of whether your work is interesting is one important measure of success. How do we determine what other researchers in the field think of your work? By their willingness to include papers you have written in their conferences and journals.

I expect graduate students working with me to produce publishable-quality research. This is an absolutely fundamental requirement – it is not negotiable and there are no exceptions. It takes some time to get going, of course, but by your second or third year working with me, you should be regularly producing research results that we can publish in well-regarded conferences and journals. If you work with me for an extended period of time and do not help generate publications, you can assume that I am not happy with your progress.

Building on this, while getting a paper published is good, it means nothing if the paper is never cited. Other researchers must be reading your papers and acknowledging the importance and relevance of your work by referencing it in their own papers. Well-written papers that address important problems get noticed and have an impact. This is your ultimate goal.

Please know that developing technical writing skills is one of the things you will learn as a graduate student researcher – again, this is a matter of “practice makes perfect.” I work with my students to help them develop this skill. The papers we write together will be a collaboration that evolves over time. At first, I may do a substantial portion of the final editing on our publications. This is most likely to happen in the early stages of your career as a student researcher. By the later stages, you should be doing most of the work described in the paper, and most of the writing, too. I strongly encourage my students to propose topics for papers and venues to publish them – this is a sign of research maturity that is critical for success in graduate school.

Becoming a member of an international research community implies other responsibilities as well. It means being aware of other research groups that do work that is similar to ours, and understanding the relationship between their work and our work. Much of this research is of high quality and deserves your respect. It is considered an insult to write a paper that ignores important related work in the field. Indeed, this reason alone may result in the paper being rejected. You should always assume there is other published research that relates to what we are doing. Finding this work and understanding its connections to our own is one of your responsibilities as a researcher. If you tell me there is no related work, my first assumption is that you did a bad job with your literature search. I look forward to students bringing me interesting new papers they find that are relevant to our research.

On occasion, we will have an important visitor in the department – perhaps a seminar speaker, or a colleague from elsewhere who we are collaborating with. In such cases, I expect you to attend the talks and meetings that may take place. This is a way of building up professional contacts which will prove valuable later when you are looking for a job. It also reflects on the reputation of Lehigh – we want outside visitors to know we have good graduate students here. It is always a smart idea to do some background reading so that you can have an intelligent conversation with our visitor, who will often be a distinguished researcher in the field.

## **6. Developing Communication and Critical Thinking Skills**

It goes without saying that I expect you to work on developing good communication skills. This means reading, writing, and speaking effectively about your research. English may not be your native language; by itself, this is not a problem. The ability to convey scientific ideas transcends knowing the finer details of the English language. As with many other skills, the secret is practice – write as much as you can, and take the time to read well-written research papers. To avoid wasting my time, do your best to eliminate as many grammatical errors as possible before you give me something to read, and always be sure to use a spelling-checker. Never give me something that is only a “rough draft” unless I ask you to do this – I am busy and do not have time to read papers that are filled with errors you should be catching yourself. It may be a good idea to ask a friend to review your writing or to attend a practice talk to offer you advice before you submit your work for my evaluation.

Inherent in communication is the concept of critical thinking. This involves developing a deep understanding of what we are trying to accomplish as well as the related literature. You should be able to read a paper connected to our work and identify its good ideas as well as its limitations. Published papers sometimes contain exaggerated claims, faulty logic, or even outright mistakes. As you learn to identify such problems in papers by others, you should work to eliminate them from your own writing.

While refining your communication skills is a natural part of becoming a researcher, muddled writing can imply muddled thinking. This is a more serious problem, and usually not correctable. As a general rule, a good advisor looks to spot the differences between these two cases.

If you believe you need help in becoming a better writer or speaker, let me know – there are resources available on the Lehigh campus to help graduate students learn these important skills.

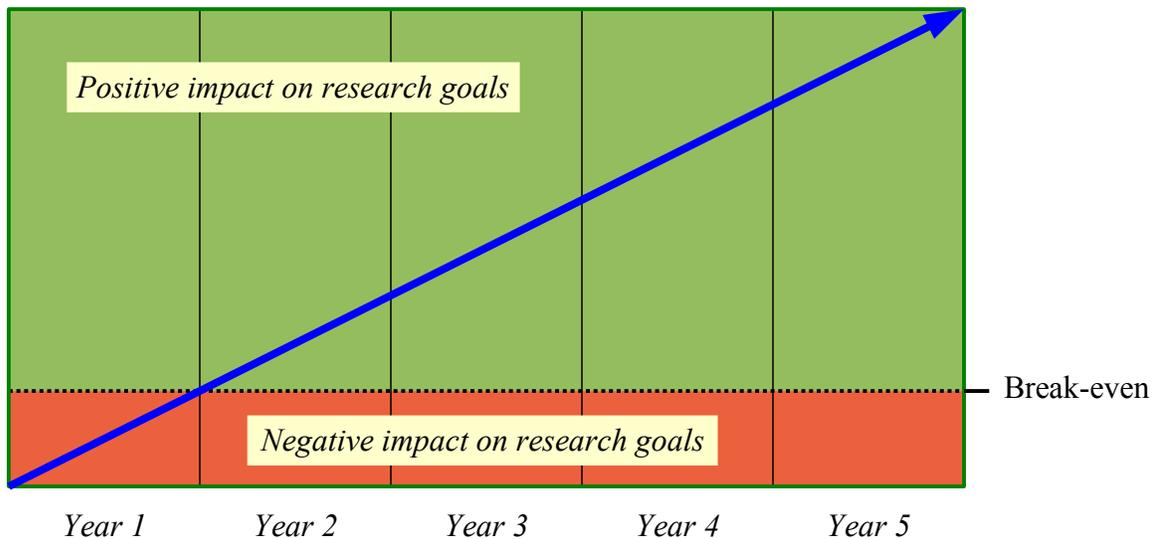
## **7. Productivity**

I invest my time in mentoring students because I expect they will someday become productive researchers and, at that point, my investment will pay off. Productivity can be measured in research results, papers, and technical reports. Having your name on a paper by itself is not sufficient: you must have done a significant part of the work to deserve full credit.

To be clear, ultimate success in graduate studies is not determined by how nice you are, whether you get good grades, or how many hours you work in the lab. The overriding consideration is whether you are making a contribution to advance the research.

It may help to think of this as the following “Return on Investment” curve. In your first year, I expect that I will invest more time in mentoring you than you will return in advancing the research. After that point, you should show signs of driving the work forward on your own. In later years, every hour of my time should yield increasingly more than an hour's worth of results. This is the natural progression in becoming a productive researcher, as depicted below. In the red-shaded region, the student produces less than one hour of results for every hour I invest. In the green-shaded region, the student produces more than one hour of results for every hour I invest. The unit of measurement is the amount of work I could do in an hour, since the trade-off involves my supervising you versus doing the work myself.

This figure also indicates that five years is a reasonable length of time to earn a Ph.D. (I finished my graduate studies in four years.) You should not expect to receive financial support after the fifth year. If your early trajectory suggests you have no chance of completing an acceptable Ph.D. in five years, I will end your funding and encourage you to look elsewhere for graduate school.



While each student may progress at a somewhat different rate, as a general rule here are some guidelines for what a successful Ph.D. student should accomplish in each year working with me:

- Year 1** By the end of the first year, you should be familiar with one of my research topics. You should know a specific segment of the technical literature connected with the problem very well, so that you are able to have an extended discussion with me about it. You should have made a clear contribution to the project, most likely by writing some programs to support experiments we want to perform. You may have provided a write-up describing the results of your experiments for inclusion in a paper we are planning to submit to a conference. You will also have completed all of your courses for the year with high grades (A or A-), and you will have taken and passed your first-year examinations (the precise requirements differ for Computer Science and Computer Engineering students).
- Year 2** By the end of the second year, you should be fully integrated with one of my research projects. You should know a broader portion of the technical literature connected with the problem, so that you are able to suggest ideas for extending our research in new and interesting ways. You should be able to recognize the differences between good work and bad work that has been done in the area. You should have made significant contributions to the project by writing programs, conducting experiments, and preparing technical reports and write-ups for conference and workshop papers that we submit. By this point, you should have earned co-authorship on two or more published papers with me. As in Year 1, you will have completed all of your courses with high grades (A or A-), and you will have taken and passed any necessary second-year examinations required for the degree program you are in.
- Year 3** By the end of the third year, your program as an independently-functioning researcher should be well-developed. You should be an expert in the technical literature for your problem area, and you should be working on promising approaches that you yourself have proposed in consultation with me. Your contributions to our project should be substantial, reflecting several years of hard work. You should be authoring publication-quality conference and workshop papers with only modest amounts of my feedback. By this point, you should have earned co-authorship on four or more published papers with me. I should have enough confidence that I am able to assign you as a reviewer for submissions to conferences I help

organize. As in previous years, you will have completed all of your courses with high grades (A or A-), and are on track with all other aspects of your Ph.D. program.

**Year 4** By the end of the fourth year, you should have completed a substantial portion of your thesis research. You should be regularly writing papers that we are able to publish in high quality conferences and workshops (at a rate of several papers per year). The draft papers that you prepare at this point require only minimal feedback from me. In addition, you should have at least one journal submission in the process of being accepted for publication. Your expertise in our problem area should be starting to receive outside recognition. For example, you will be increasingly asked to review paper submissions by others, or may even be invited to serve on the organizing committee for a technical meeting. Your high-quality results will have helped us obtain additional research funding in the area. In addition, you will also be serving as a leader in our lab, helping newer graduate students get up to speed on our research. As in previous years, any courses you take will be completed with high grades (A or A-). You will have taken and passed your General Examination and, in the best case, you will have defended your thesis and completed your degree.

**Year 5** If needed, by the end of your fifth year you will have built on your successes from previous years, publishing even more extensively in the scientific literature. By this point you should have had at least one high-quality journal paper accepted for publication, and at least one more journal submission in progress. You will continue to publish in our best conferences and workshops. Your expertise now being widely recognized, you will have been invited to give talks on your work at other universities and research labs. You will have defended your thesis and completed your degree.

## **8. Deadlines and Degree Requirements**

Whether you are striving to earn a Master's degree or a Ph.D., the programs at Lehigh have various requirements. There are certain courses you must take, and examinations you must pass. Knowing these rules and deadlines and making sure you satisfy them are your responsibility – do not expect me to remind you. If you fall behind, your funding may become at-risk. The Director of Graduate Studies and the department secretary who works with graduate students can provide helpful information.

## **9. Standards**

As I have already noted, some people who are “A” students do not measure up to be “A” researchers. I demand that the work done under my direction be of very high quality. Keep in mind this means my standards are the ones that apply, not your past teachers' or your own. It should be obvious, then, that you need to learn my standards and find a way to meet them if you want to succeed. While I do not typically give a grade for research efforts, you can still regard the following levels as guidelines:

Excellent	Well thought-out, carefully documented contributions to the project. Shows outstanding effort and creativity. Knowledgeable about related research. Work publishable in a high quality conference or journal. Meets with me often and always has something interesting to say. Suggests ideas that did not occur to me first.
Concern	Does the minimum suggested, but nothing more. May be devoting time to the project, but work is not good enough to have a significant impact. Can quote what others have said, but does not have anything new or interesting to add. This low level of

performance will lead to my dropping the advisee unless there is improvement.

**Unacceptable** Misses deadlines and/or meetings. Makes no contributions to advancing the research. May ask frequent questions, but never ones that reflect a deep understanding of the work. Has ignored repeated warnings and suggestions for improvement. I will not continue to advise or support such students.

You will note that there is no “Average” or “Acceptable” level of performance – this is what I mean by having high standards. Either you are doing excellent work, or you are on a path that falls short of what I require of my students. If you want to know your current level of performance, just ask me.

A smart way for you to start to learn my quality standards is to seek out and read some of my published papers, which you should be able to locate online.

## **10. Role of the Advisor**

I have mostly said what you must do to be successful. What will I do? You will find that the right advisor – whether it be me or someone else – can be a valuable resource. The list of ways an advisor can help you is long and open-ended. Most importantly, of course, an advisor will help you identify research questions worth studying, start you off in the right direction, and keep you on track as the research progresses. An advisor can also assist in providing you with the professional contacts that may lead to your first job (or perhaps a later one), helping you find answers to questions you think are unanswerable, offering guidance on a variety of academic and technical issues, locating and acquiring software and equipment you need to succeed in your research, arranging for funding (in some cases) to help support you during the summer and/or academic year, and making sure your work receives the recognition it deserves within the Lehigh community as well as the outside world.

## **11. Student Funding**

Recall my earlier comment that doing research is not like taking a regular course. In fact, a research assistant is more like an employee than a student. This means you are not paying me to teach you, as was the case when you were in college; rather, you are being paid to help me conduct research. If you do not contribute, I may be forced to turn elsewhere to get the job done and you will lose your financial support. To fully fund a graduate student costs an advisor approximately \$50,000 a year, including tuition and stipend. This funding is a privilege – it is not a right.

It is easy to get distracted by the courses you are taking and ignore your research. Courses have concrete schedules, assignments with specified due dates, and pre-determined quizzes and exams. If you ignore your research to focus too much on your courses, you may find that you get good grades, but that I am no longer willing to fund you. This seems like a small victory at best. I will not accept a heavy course workload as an excuse for falling short on research, so do not bother to ask. It is your responsibility to schedule enough time to make progress in your research.

As a rule, I do not provide funding for Master's students. A Ph.D. student will typically receive two years of funding to demonstrate the potential to do high quality work. By your second year, you should be fully engaged in original research if you hope to receive continued funding (recall the ROI curve I provided earlier). Research grants are highly competitive and winning them takes a lot of effort. We are awarded grants because funding agencies believe we can do a first-rate job. If you are put on a project and do badly, it wastes the sponsor's money and reflects negatively on me.

It is an unfortunate fact of life that most research grants last for 2-3 years, whereas it often takes 4-5 years to earn a Ph.D. This means that there may be times when your financial support switches from one project that is ending to a new one that is starting. The topic areas for these projects will often overlap, so the disruption should be minimal. In the worst case, there may be gaps in funding that we have to try to cover in creative ways. The effort I will devote to finding funding for a student is directly related to the quality of work that student is doing. If you are doing great research, I will do everything possible to find funding for you. I have no interest in spending time trying to find funding for students who are doing poor quality work because there is no payoff for having such students on a project.

You may begin your graduate studies at Lehigh with a university fellowship or a position as a Teaching Assistant in one of our courses. This means you are not being paid directly to help with research. It is important to realize, however, that such arrangements are usually short-term and will last for only a year or two. It would be a mistake to think that you can waste this time and ignore the need to become involved as soon as possible in research, either mine or another professor's. Before I even consider offering support to current students, I demand strong evidence that you can contribute to one of my projects. Waiting until the last minute to try to show you can make a contribution is a bad idea.

It should be noted that the very best students can sometimes obtain outside funding on their own. In a field as important to society as computer science and engineering, there are numerous opportunities for fellowships and scholarships. Making the effort to explore such options shows good initiative, and removes some of the financial pressure that graduate students sometimes experience. (I had a fellowship from the State of New Jersey when I attended graduate school.) But even if you find a way to fund your own graduate studies, keep in mind that my comments concerning productivity still apply. I expect all of my students to make significant contributions to the research effort, otherwise it is a waste of your time and my time for you to be in the Ph.D. program.

## **12. Conference Travel**

One of the rewards for contributing to a successful research project is the occasional chance to attend a scientific conference in the area of our work. Because such travel can be expensive, it is not always possible to send a student to present a paper, but I will let you know when that is an option. Do not ask me about this – I will tell you. Overseas travel is much more expensive than domestic travel and hence less likely to receive support. There are many rules and policies when traveling on official business, so make sure you know them before planning a trip, otherwise you risk not getting reimbursed. Also remember that when you travel to a conference, you are representing me as well as Lehigh. I expect you to take such travel seriously, to dress neatly, to attend the technical talks and other conference activities, and to attempt to be cost-conscious when making your travel arrangements.

## **13. Stress and Personal Issues**

Graduate student life can be stressful. If you have been a good student in the past, you may find that this is the first time in your life there is a risk you might fail to finish something that you started. The financial challenges of paying for graduate school also may trouble you. Sometimes family or personal issues arise which add stress. You should know that there is always help available for you on the Lehigh campus. The Graduate Student Life Office, housed in Christmas-Saucon Rooms #036 and #038, is an excellent resource for students.

#### **14. A Note on Success and Failure**

You are a good student, otherwise you would not have been accepted into Lehigh. Graduate school is not right for everyone, however. It is important to realize that acceptance into our program is not a guarantee of finishing a graduate degree. Unlike undergraduate studies, where nearly everyone finishes successfully, many smart graduate students never complete their Ph.D.'s. There is no dishonor in this. Indeed, such students often go on to have successful careers, with the most obvious cases being Larry Page and Larry Brin, the two founders of google who dropped out of the Ph.D. program at Stanford and who are now highly successful industry leaders (and billionaires).

Being a good student is a necessary pre-condition for success in graduate school, but it is not sufficient in itself. You must be creative, inquisitive, dedicated, intelligent, driven, curious, and resourceful. Either you possess these qualities or you do not – there are no miracles – they cannot be learned and I cannot teach them to you. The most I can do is give you the opportunity to demonstrate that you have these qualities, and then help you develop them if they are present.

The university, the college, and the department all prescribe various hurdles that graduate students must satisfy. In addition, you should assess your own progress on a continual basis. If things are not going well and your research is not advancing under the criteria I have just described, it is best to be honest with yourself and begin investigating other career options. There comes a time when students who are not making a significant contribution can no longer be supported financially.

#### **15. Summary: Basic Qualities for Success**

The qualities necessary to become a successful researcher are similar to those needed for success in other parts of life. They include:

- Creativity – finding solutions to hard research problems requires thinking in new ways, bringing together ideas in ways no one has tried before.
- Initiative – you must drive your own research forward. You should not depend on anyone else to outline each step and walk you through it by the hand as though you were still in college.
- Tenacity – hurdles constantly arise in the course of doing research. A good researcher is not willing to give up, always believing there must be a way around the current stumbling block.
- Maturity – strive to understand the big picture, learn what you need to do to succeed, and do it. Realize that your work is part of a larger puzzle and that other people are depending on you.
- Attention to detail – to solve a problem no one else has been able to solve, you must know it better than anyone else. If there are important points you do not understand, or related work you have not studied, the likelihood you will make a useful contribution is small.
- Confidence – an appropriate level of confidence is vital for a successful researcher. This is a quality that you will develop over time. Keep in mind that, while you have already proved yourself to be a good student, proving that you are a good researcher requires demonstrating a different set of skills.

Please keep in mind that no document like this can ever be completely comprehensive: every student research experience is unique. The most important piece of advice to keep in mind is that if you ever have questions or are unsure about something, ask me! If you do not approach me, I cannot help you.