

# NAVIGATING THE PH.D.: STRATEGIES FOR WOMEN IN ENGINEERING AND SCIENCE

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**Abstract**—This paper is based upon findings from the authors' recent book, *The Woman's Guide to Navigating the Ph.D. in Engineering and Science* [1]. Here, we present some typical challenges that women may face in engineering and science doctoral programs, and offer strategies that can be undertaken by individual students and by institutions to enhance the success of female engineering and science doctoral students. We focus on challenges that fall into three categories: (1) discovering "hidden" rules for navigating the doctoral program, (2) finding and working well with one's advisors, mentors and friends and (3) adapting to the environment. Interwoven throughout are reflections and insights from women who are working toward or who have completed doctorates in engineering or science.

**Index Terms**—advisor, doctorate, mentors, requirements

## INTRODUCTION

Depending on the field or the university, women sometimes comprise but a small minority of the doctoral students in engineering or science departments. Due to outside influences, navigating the Ph.D. in those fields can prove difficult for a woman today, but it was nearly impossible just over 100 years ago.

Until about 1890, women were not formally admitted to doctoral programs at any university in the United States—although women did find ways to get in, usually as "special" or nondegree students. In 1870, for example, Ellen Swallow Richards applied to the Massachusetts Institute of Technology for a graduate degree in chemistry. She was admitted, but as a special student who was seeking a second bachelor's degree (her first one was from Vassar). It was argued that MIT didn't want its first graduate chemistry degree awarded to a woman [2].

Even after being admitted, however, women still had to struggle to be awarded the degree for the work done. One of the most infamous examples of this discrimination was the case of mathematician Christine Ladd-Franklin, who completed her dissertation in 1882 at Johns Hopkins University but was not awarded her degree until forty-four years later [2].

Between 1890 and 1892, women began to be accepted for graduate study by Yale, the University of Pennsylvania, Columbia, Brown, Stanford and the University of Chicago. Other universities soon followed and, by the early 1900s,

women were being admitted to most graduate programs [2], and, by 1940, were earning 13% of all doctorates [3].

In the past thirty years, numbers of women in graduate engineering and science programs have increased dramatically. In 1970, women earned just 13% of life science doctorates [4]; today, they earn more than 40% of those doctorates [5]. In 1970, women earned just 3.6% of engineering, physics and mathematics doctorates combined [4]; today, 13% of engineering doctorates are earned by women. Although figures are looking up, there is still concern that the number of engineering doctorates earned by women is still quite low. After all, for the past twenty years the United States has faced a critical shortage of scientists and engineers with doctoral degrees in a number of fields.

Why aren't more women earning their Ph.D.s in science or engineering? The answers are complex but have a great deal to do with the nature of doctoral education, the atmosphere and largely unconscious attitudes and cultural biases in many graduate programs in the sciences and engineering. For our recent book, *The Woman's Guide to Navigating the Ph.D. in Engineering and Science* [1], we interviewed dozens of women who are enrolled in or who have completed doctoral programs in engineering or science. Also drawing upon the literature and the co-authors' work with graduate students at Carnegie Mellon and beyond, the book provides an overview of what any doctoral student faces in an engineering or science doctoral program, but particularly focuses on the unique situations female students may experience. In this paper, we present some of the major challenges women may face in engineering and science doctoral programs, and share both individual and institutional strategies that can alleviate or eliminate them. The challenges that we present fall into three categories:

- discovering the "hidden" rules for navigating the Ph.D.
- finding and working well with advisors, mentors and friends
- adapting to the environment

## DISCUSSION

### Discovering the "Hidden" Rules

Coursework, teaching, research, thesis-writing—the work that a student must accomplish in a doctoral program can be grueling. But the difficulty of these tasks can be exacerbated

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by not knowing what is expected to fulfill degree requirements or to “fit in” to the department or program.

Women in particular may come up against such invisible barriers within the graduate school system. Many of these barriers are also invisible to the men in the environment, who may unwittingly participate in perpetuating the system. When questioned if they’re supportive of women in their departments, these men may answer “yes,” but unknowingly have access to information and contacts their female counterparts do not. The barriers—and the system—are unknown to most women because of their status in the environment. Whether by design or default, women may find that they are not privy to the secrets of successfully maneuvering the system, and too often blame themselves for faults that are part of that invisible system. In some cases, women are welcomed with open arms to academic departments but are still isolated by a system put into place well before their arrival.

**Challenge:** The first problem any doctoral student may run up against is a lack of uniform requirements and standards for completion of the program. Each college and department within the university may have different rules and requirements concerning its graduate students—everything from admission to funding to degree completion. In some cases, standards and requirements may even vary among students within a program or department. A study by Mary Frank Fox showed that this decentralization can be even more pronounced in engineering and science departments, where funding is dependent upon research grants awarded to individual faculty. Because of a university’s dependence on this income, faculty are given a great deal of latitude in advising their graduate students [6].

**Individual Strategy:** Because of the freedom that advisors may have in interpreting thesis- or degree-completion requirements, it is very important that the student familiarize herself with all written requirements (both obtained from the department/program and from the advisor) to avoid any potential problems.

**Institutional Strategy:** Departments or programs should develop—and keep updated—written requirements for their doctoral students. Although this seems like it would be a given, such a seemingly simple operation might not have been undertaken. Reasons for not having such documentation can range from administrators not thinking it’s necessary to it not being clear whose job it is to maintain the document. Having a set of standard requirements for degree completion, however, can save a lot of time and agony for both the students and the department or program. Such a document can alleviate students’ worries about not understanding what is required of them and reduce the number of grievances that students bring to the department.

Such a document presents to all students what is required of them, eliminating as much as possible the

students’ reliance on word-of-mouth information that may not be shared with all students equally. In addition, a written set of requirements (or any important information that a department or program wishes its students to know) particularly helps the student who may be a minority in the group (such as a woman), but also helps international students whose command of written English may be better than their command of spoken English.

(Interestingly, Fox found in her study that chemistry and computer science departments—two fields with higher proportions of women—were more likely to provide written guidelines for degree completion than electrical engineering and physics—the two fields in her study that had lower proportions of women. [6])

Another useful tool is an annual written progress report prepared by the student’s advisor. Such a report lets the student see how her work is progressing from her advisor’s standpoint and according to the program standards. It also lets her see what her goals should be for the coming year or so. A top administrator at a major research university comments that these written progress reports are especially useful in the sciences, where a student may have been told she needed to complete three experiments but the requirement is then bumped up to four because she accomplished the first three so quickly. Written guidelines and annual progress reports help keep requirements clear.

**Challenge:** In some departments, the requirements for completing the degree are passed down from person to person, advisor to student, and a woman entering into a predominantly male arena may not necessarily be told the requirements and may be hesitant to ask what they are. A woman may find that she is not part of the same social and recreational environment as her male colleagues. The male students in the department may play tennis or racquetball or go out for beers with male professors or other students in the department and, through that interaction, learn more about “the system.”

**Individual Strategy:** Good data can level the playing field. Socializing is one method for gathering that data. Dr. Cinda-Sue Davis of the University of Michigan emphasizes the importance of attending social events for grad students, not just for their “own sanity (which is probably the most important reason), but also because a lot of accessing unwritten rules happens in these social events.” (Socializing also helps the student adjust to her new environment and helps establish a set of friends who will be there for camaraderie, feedback and support throughout the doctoral program. See more under the next section, “Finding and Working Well with One’s Advisors, Mentors and Friends.”) Davis also suggests asking senior graduate students, “What do you know now that you wish you knew when you started?”

**Institutional Strategy:** Departments or programs should hold social events for all students to attend early in the fall

semester so that new students can start building a network of peers to share information with throughout their doctoral program. If departments or programs don't hold such events for all students, then there is the great chance that students will immediately break off into cliques that will ultimately leave some students disconnected and uninformed. Ideally, graduate students will also have a physical space, such as a grad lounge, outside of their offices to congregate and meet informally. A central location where all students in a program or department are welcome and comfortable is an excellent setting for sharing useful information.

The department should also strive to maintain a friendly working atmosphere where information is shared among all graduate students in a program. Nothing can be lost by keeping all students well informed of administrative changes that affect them.

### **Finding and Working Well with One's Advisors, Mentors and Friends**

When a student enters a doctoral program, it's the beginning of a long and arduous—but exciting—educational adventure. Over those next few years, the student will work closely with both superiors and peers. She will form professional relationships with some and close friendships with others. And as she goes through this very important phase of her career, she will rely on that network of people to talk with, get feedback from and offer help to.

The most important professional relationship a student will have in graduate school is with her advisor. Her success as a student depends on it, and the course of her career may depend upon it as well. The advisor is an indispensable resource. She or he suggests what courses to take, directs the program of study, supervises research and chairs the student's dissertation and oral exam committees. At best, an advisor is a confidant, mentor, sponsor and major advocate in the department now and later in the student's career. The advisor can be the launching pad for the student's career by providing the opportunity to work on well-funded projects, by introducing the student to contacts and influential people in the field and by providing opportunities to exercise the student's skills outside of the university. Ideally, the relationship between the student and her advisor will progress during her time in graduate school from that of teacher and research director to that of mentor and professional colleague.

(Note: When applying to graduate school at a particular university, the student should learn how the advisor matching process works there. If a student is assigned an advisor upon acceptance, she should carefully weigh that assignment as part of her total acceptance decision. In our discussion about choosing an advisor here, we assume that the student has not been assigned an advisor, but is free to choose her own. In addition, we understand that the words "advisor" and "mentor" are used interchangeably in some departments or by some individuals; here, we refer to the

advisor as the person who helps guide the student's research and provides her funding.)

**Challenge:** Women in science and engineering sometimes find it more difficult to find a suitable advisor. For instance, a female student may prefer to have a female advisor so as to serve as a role model, but there may be very few women in the department. In addition, some of the potential male advisors in the department may not understand a female student's needs simply because their own experiences have been different.

For some women, part of the criteria when choosing an advisor is whether or not that individual can provide the intellectual reinforcement and emotional support they may need. Often, a female student cannot or will not share her concerns because she fears confirming the suspicions that women aren't good enough or tough enough to make it in graduate school. In addition, many women avoid the very contact that might help them, such as asking questions or requesting help with difficult material, because they fear being perceived as weak or stupid. Advisors sometimes either overtly or covertly minimize these feelings, and many women become frustrated and disappointed with the person they should trust the most.

**Individual Strategy:** Finding a good advisor is not simple, but it can be done, even if the "perfect" match never happens. Since universities differ in how students are matched with an advisor, the student should understand how the advisor-pairing system works and make that part of her admission decision.

If a student has the freedom to choose her own advisor, she should follow these guidelines:

- If possible, choose a faculty member who shares your interests, philosophies and general world view. You want to choose someone with whom you feel comfortable and who will give you the individual support you may require. Try to get acquainted with several faculty members in your department before making a definitive choice. Ask the opinions of other graduate students.
- Make sure you can get along with a potential advisor on both a professional and personal level. You will be spending a great deal of time together—in most scientific fields, five or six years—so you need to work together comfortably. You and your advisor should be able to communicate openly and honestly. This doesn't mean that you and your advisor should be best friends, just that you can work together professionally.
- Ask around the department about potential choices. Find out how a certain faculty member has interacted with other graduate students, if she or he has previously served as an advisor, and what her or his philosophy is on the "graduate school experience." It may be to your advantage to determine if your potential advisor is well-

connected in terms of financial support and outside collaborations.

- See if you can find out if your potential advisor will be on campus long-term—for the next four to five years. If there is a possibility that he or she will move, think about your options: would you move along with your advisor, or would someone else in the department be able to take you on as an advisee?
- Consider the issue of junior vs. senior faculty status. Senior faculty members are presumably better connected both within and outside the university. On the other hand, a junior faculty member may be able to spend more time with you, but in some instances may be too busy launching her or his own career to advise you properly.
- If your first choice for an advisor is not available or suitable for one reason or another, or if you're torn between two choices, you may still be able to have that person on your dissertation committee or work with him or her in some other capacity.

**Institutional Strategy:** One professor offers this strategy: "Hire more women faculty!" A shorter-term answer might be to gather information on how well current faculty are advising their students. How many female American Ph.D.s has Dr. X graduated? Why are some advisors successfully graduating more women than other advisors? Using this information and other literature on the subject, departments can educate potential advisors on how to best advise their female doctoral students.

A good advisor should:

- Help to direct and involve the student in her areas of interest.
- Introduce the student to the department and the scientific community, and "plug" her work.
- Counsel the student and direct her research as candidly as possible, remaining sensitive to her interests and intellectual opinions.
- Assist in the student's course selection.
- Guide and protect the student from troublesome people in the department and help her to understand and learn to negotiate the politics of the department and school.
- Offer encouragement as the student "learns the ropes" and attempts new things.
- Help the student to understand and meet deadlines within the department.
- Provide opportunities for the student to attend and/or participate in professional meetings to become part of the academy.
- Ensure that the student publishes her work in appropriate archival journals.

**Challenge:** A student will rarely find an advisor who will meet all of his or her needs intellectually, socially and emotionally. The student may be having trouble with writer's block or passing the qualifiers, but his or her advisor

may not be able to sympathize or even fathom such a concern. Due to her minority status as a woman in an engineering or science department, a female student may have an even tougher time finding an advisor who can provide support and feedback in all the areas she needs. For instance, a female student may be experiencing a situation that is distinctly gender-related, such as pregnancy or discrimination by some faculty or other students.

**Individual Strategy:** Although officially a student has one advisor—the person who heads her thesis committee and supervises her academic program—she will want to put together a network of other individuals who can provide additional advice and support to make dealing with the challenges of graduate school much easier and more pleasant.

As the student interacts more closely with faculty in her department, she should single out people she believes will give her the critical feedback and personal support she may want. She may also find that outside resources such as female faculty members in other departments, academic support groups, religious organizations or even e-mail communities can provide meaningful support and critique of one's work.

A student shouldn't overlook other graduate students—both women and men—as sources of support and advice. Although faculty members are important to a student's professional development, graduate students—within and outside the department—can be invaluable. Current peers will be the student's professional colleagues in the future; and, in some cases, they may be her best source of professional and personal support. As several graduate students advise: A student should watch out for being labeled "too emotional" by faculty, and should find graduate students to share feelings with instead.

**Institutional Strategy:** Institutions should educate their graduate students on the legitimacy of the team-mentoring approach. Many students rely solely on their advisor for both professional feedback and moral support—incorrectly assuming that "advisor" always equals "mentor." Some students don't realize that it's acceptable—and often necessary—to go to others for additional professional and personal support. To help students broaden their network of advisors, mentors and friends, institutions can provide a variety of organized programs such as those that bring together female professors and students for networking luncheons or that match female students with female mentors in their field.

Institutions should also have at least one senior university-level administrator to whom graduate students can come with serious grievances. While it's usually best to settle grievances quickly and locally, sometimes it's just not feasible or comfortable to go to one's advisor, department head or dean. A university-level ombudsman will often have dealt with similar issues and can advise the student on what

informal or formal steps can be taken to remedy the situation.

### The Importance of Having a Mentor

As one seasoned engineer observed, "Successful people have mentors; they don't just get there on their own."

Mentoring can take many forms and goes by many definitions, but generally it means having a senior, experienced person in the field who is willing and able to provide advice, wisdom and support as the student is finding her way in her chosen discipline. Mentoring can be on an arranged or formal basis (such as being matched up with a mentor through the department, an honor society or a mentoring group), an informal basis (having coffee with a former professor once a month) or even on an electronic basis (such as through MentorNet). It can be on a daily basis or on an as-needed basis. A mentor may be sort of a surrogate parent, someone who takes the student under the wing and guides her and nurtures her development. Or it could be a faculty member who simply continues to teach the student outside of the classroom, offering up knowledge about things the student will need to know about how to be successful in her field.

The student should realize that what she needs from her mentor may not be what that person is willing or able to offer. She may want her mentor to help with the politics of the department, to give emotional support during writer's block or to help her find a job—but he or she might not have the resources, knowledge or desire to help the student with all of her needs. Or the reverse might be true: the student's mentor wants to help more than the student wants to be or needs to be helped. Because of all of these factors, students need more than one mentor to draw from or fall back on. No one person can provide everything a student needs in finding her way.

"We all have many mentors," says Anita Borg, computer scientist at Xerox and president of the Institute for Women and Technology. "However, there are times when a more formal mentoring relationship is really useful. It's important in a formal mentoring relationship that there be some training and understanding about what that means for both parties. But once that relationship is established, it has to be the mentee's job to drive the relationship. A mentee can't just sit back and say, 'So what are you going to do for me?' Only the mentee knows what she wants to get out of the relationship." [1]

### Adapting to the Environment

Fitting into an engineering or science doctoral program doesn't have to mean being "agreeable" to everything and with everyone. For some women, learning how to fit in means learning how *not* to be a "nice" girl; that is, learning how to deal constructively with criticism and how to support one's ideas in argument.

The fundamental purpose of a doctoral program is to help the student become a professional who generates ideas within an extremely specialized field. Undergraduates spend most of their time reading and writing about established theories and research. By contrast, doctoral study challenges the student's ability to learn in a completely different way. It

focuses study in one discipline, and requires that one conduct original research and formulate her own theories.

**Challenge:** As she progresses in graduate work, most of the student's learning will come through a series of formal and informal exchanges in which others—both faculty and peers—will challenge and test her ideas. As her research progresses, she is expected to share and discuss her findings with others in the same manner. We refer to this as "learning by critique," which is the foundation of the graduate school experience.

Many women perceive the insistent questioning involved in learning by critique as harsh and negative, or as a personal attack. When a professor asks questions and continually challenges students' reasoning, many women feel that the professor is commenting on their intelligence or worthiness as a graduate student. Some report feeling uncomfortable or unworthy for asking "too many questions" or for presenting new ideas.

While some women can positively respond to learning by critique, many internalize the criticism. Professors may believe that they are pushing a student to explore new areas and to think independently, but a nonconfident female student may only hear "you're wrong and you don't belong here."

**Individual Strategies:** Following is some advice by graduate students for meeting the challenge of learning by critique:

- Set realistic goals. You are not going to know everything the minute you start graduate school. Remember, you're here to learn.
- Recognize that many things can only be learned through the process of trial and error. When you make mistakes, focus on what you can and did learn from it.
- Talk to others about your experience. Older and more experienced graduate students, faculty members, counselors all understand what you're going through, and many of them have already been there.
- Realize that you can never be completely prepared for everything. Go ahead with your work, and if you find you're lacking in a certain area, do what you need to improve. Don't judge yourself too harshly.
- Ask for what you want. Your professors are there to help you, but may be oblivious to your concerns and may forget how it feels to be critically evaluated.
- Try to objectively evaluate the comments on your work, and then make a rational decision about whether or not to open a discussion or a debate. Women are more likely than men to believe that negative feedback is justified and to keep quiet, but should realize that criticism is usually just opinion.
- Feed your self-esteem bank by remembering your successes. Remember those times when you have asked the 'right' question or solved a difficult problem. You'll soon realize you have what it takes to make it.

- Remember that time will help you feel more confident. As a first- or second-year Ph.D. candidate, it's difficult not to feel hopelessly clueless. As you define your interests and begin work on your own research project, you will undoubtedly develop a stronger sense of yourself and your own abilities. [1]

### A Survival Strategy

"Men are often shocked at how personally women take criticism and the only thing I can say is that until there are more women working in non-traditional fields, we have to learn to play by those rules as best we can because we're never going to make it if we don't. You can't change the fact that you put your heart and soul into the work and that it is personal, but you can adapt, adjust and develop mental strategies for understanding that something might not be a personal criticism even though it's a very directed critique of your work. Negative feedback doesn't always mean that you're wrong; it means that the person disagrees or is trying to make your work better. When someone says, 'Here's a place where I don't think your work is very good; here's how you can make it better,' it's not the same as 'You're bad, you did it wrong.' The mental strategy has to be to see how they see it, and try to react to that. That's the only thing I've been able to do to survive, and it works pretty well. That's what the guys do. I'm not satisfied with it in the long run, but it's a survival strategy."

— Ann, doctoral student, biology [1]

**Institutional Strategy:** Institutions should work to inform their female students about these common gender behavioral differences. New students can be matched up with other, more senior women in the program or department so that they can be informally advised on many aspects of what it's like to be there. In addition or alternatively, the networking luncheons mentioned above or a special seminar on the topic can provide an atmosphere where such issues can be discussed openly.

**Challenge:** The women in engineering and science doctoral programs are at least as smart as the male students, but the two sexes generally argue differently—and that may give the males an edge. A 1990 study showed that women are more concerned than men about the damage that an argument might cause in an interpersonal relationship. In general, men who argue are regarded as "rational," while women who argue are deemed "disagreeable." Therefore, in fields where argument is necessary, women are at a disadvantage when dealing with male peers. (This gender difference—whether true for an individual or perceived as true by others—can also prove to be a disadvantage in working with a male advisor. If a male advisor believes that a woman may react more "emotionally" to criticism, he may not give her the feedback she needs to make her work better. And so the female student is denied an advantage that the male student is not, through no fault of her own.) [7]

Another typical difference is that male students tend to be more aggressive than female students in working with lab partners on experiments, using the computers or speaking up in class or group discussions.

**Individual Strategies:** Some women see learning this type of aggression as simply another skill to master along with their studies. "You have to learn how to operate by the rules of a 'foreign' culture," comments Katrina, a recent civil engineering Ph.D. "Plenty of women believe in their own intellectual abilities (why would they be there in the first place if they didn't?), but feel like they've been hit by a truck the first time they experience a typical argument in a research group. The aggression levels are high, but they're not meant to hurt. In the minds of the guys it's just part of how the game is played, and part of the reason for being there and enjoying it . . . it's a part of their culture, a part of their pleasure function." [1]

Lillian, a doctoral student in physics, shares her strategy: "In high school there were predominately boys in the classes I was taking, such as the advanced placement math and science. And what usually happened was that since I was very quiet and shy, I got overshadowed a lot. One day in my physics class I realized that I was going to have to start being bossy and stand up for myself. All the guys were crowded around the stations and I couldn't see a thing. I had to climb on top of a table to see what was going on in the experiment.... At that point I just decided I had to be a little bit more aggressive. You can't survive if you're timid." [1]

**Institutional Strategy:** Again, the institution can match new female students up with more senior female students in the program or department to provide a situation where such issues can be discussed. Faculty and male students can also be made aware of these differences, so that they can take steps to remedy any inappropriate practices or behavior.

### Breaking Loose

Nancy Hutson, who holds a Ph.D. in physiology and is Vice President of Strategic Management for the Central Research Division of Pfizer Inc., comments:

"Make no mistake, sex and gender are not the same. Sex is genetically determined, universal, and unchanging. Gender represents those behaviors taught by society and that therefore differ from culture to culture. To a very real extent, our society still mandates that women should be distinct in their behavior from men; more passive, less competitive, and less aggressive. So the first thing we must do is break loose from our gender restraints and, instead, listen to our inner voice. Science, by its very nature, demands confidence, assertiveness, and a competitive streak that will drive one to be the first to make and report an observation."

From "Women Drivers" in *Women in Science and Engineering: Choices for Success* [8]

### CONCLUSION

For women to survive and thrive in engineering and science doctoral programs—and to emerge ready for careers in the academy, industry or in the public sector—they must overcome stereotypes and hidden barriers. Women must also learn how to maneuver in a predominantly male environment, how to think like academics and how to be politically astute. The challenges presented here are but a few that women may face in the traditionally male-dominated fields of engineering and science. While it is important for female engineering and science doctoral students to recognize that they may face challenges such as we have described, the institution must also recognize and work to remedy the inequities. Together, individuals and institutions can break through the hidden barriers that women still may face in male-dominated fields, and keep the stories of Swallow-Richards and Ladd-Franklin where they belong—in history.

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### NOTES

Graduate students' names were changed to protect their identities.

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