

JOURNEYS OF WOMEN IN SCIENCE AND ENGINEERING*

**Susan Ambrose, Kristin Dunkle, Barbara Lazarus,
Indira Nair, Lisa Ritter**

**Carnegie Mellon University, Pittsburgh,
Pennsylvania**

Women in engineering and science are remarkable, in part, simply because they are so few in number. Despite the progress of recent decades, compared to men, a relatively small number of women pursue careers in technical fields. Many scholars have attempted to explain the discrepancy since Alice Rossi first posed the question "Women in science: why so few?" (Rossi, 1965), and a considerable body of literature has evolved that discusses the factors influencing girls' and women's decisions to leave math, science, and engineering.

To better understand why women choose and persist in engineering, science, and technical fields, a group of faculty and staff at Carnegie Mellon University undertook a project to explore the lives of contemporary women through a series of focused, in-depth interviews. Over the past four years, our team conducted interviews with more than ninety women; the result is a new book, *Journeys of Women in Science and Engineering: No Universal Constants* (Susan Ambrose, Kristin Dunkle, Barbara Lazarus, Indira Nair, and Deborah Harkus, Temple University Press), which will be

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out this summer. In this paper, several of the authors analyze the results of the observations from our many conversations with these remarkable women.

Part of the objective for this analysis is to draw lessons from these conversations—lessons that will guide the advisor, mentor, teacher or parent. In doing this, we need to draw distinctions between what we believe statistics of trends of participation or retention can and cannot do. Statistics can give us the warning — or encouraging — signs, but it is the individual story that provides the context and gives us clues about which interventions might effect change. Statistics abstract numbers from stories: they help us to decide when policies are needed or if they are working. But to learn what to do, to really complete the data, we believe that we need the ecology of the data and the stories that go with each of the individuals who make up the data.

Women's journeys in technical fields cover various sorts of terrain and can head in very different directions, taking different turns at similar junctions, or going full circle and returning to the same point more than once. Certain choices at crucial junctures make it easier to get to particular destinations, and certain skills, once acquired, make it easier to traverse particularly challenging or rough spots. Some choices lead off the journey in science or engineering altogether. It is important to remember that one can often get back on the journey as long as one is willing to backtrack, learn or re-learn required skills, and acquire the necessary tools and supplies for the trip ahead. Some women start out better equipped, some are given better directions, some are helped along the way, and some are hindered, but those with sufficient tenacity and panache usually make it to wherever they want to be.

No journey is without challenges. The literature on women in science and engineering discusses many factors that throw stumbling blocks into women's paths as they progress through their careers, and a number of factors most frequently cited in the literature as difficulties were also mentioned by the women we interviewed. Most of the women with whom we spoke had a mix of positive and negative experiences, and found the positive experiences compelling enough to overcome the negative ones. Somehow, they were encouraged or enabled to envision themselves as scientists or engineers.

This importance of positive experience is especially evident in the influence of parents and teachers. Many women we interviewed spoke of parents who provided them with science kits, took them to museums, or fostered science-related discussion around the kitchen table. Others, especially those who had no brothers, talked of parents who treated them almost like sons, teaching them how to use tools and fix things. Women who grew up on farms and ranches recall being outdoors and working with animals, crops, or equipment as being particularly good at fostering self-reliance and at ease with nature and the physical world. Others simply told how their parents had believed in them and encouraged them to follow their dreams and how this fostered the women's belief that they could do anything they wanted to do. And while some women have stories to tell of parents who didn't encourage their education, we had numerous women who spoke of the sacrifices their parents made to provide them with money, housing, or other resources for college.

I was the oldest of two girls....In my father's eyes, I substituted for the oldest son, so we did a lot of projects together, like building, painting, rewiring, and pouring concrete. I'm sure that those experiences with my father fostered my interest in science and math and that my "working mother" influenced my decision to pursue a career and family.

*Sheila Evans Widnall, Aeronautical Engineer
Secretary of the U.S. Air Force*

Numerous women told us how even one teacher or counselor who took time to encourage them to study science or engineering made the crucial difference in their choice of college major. Others spoke of the important roles mentors or role models played. Several women told us how their careers were fostered by mentors who offered tutelage, advice, encouragement, or emotional support. For others, finding a role model was as simple as reading a book about Marie Curie or an article on Jane Goodall; having someone to thus look up to and emulate helped those young women envision themselves having careers in technical fields.

*I became interested in science in ninth grade when my biology teacher, Miss Hymen, put a microscope in front of me....Soon after I read Paul Dekruif's book, *Microbe Hunters*, which was a detective story written for teenagers about the lives of several famous scientists like Pasteur and Lister. That book really heightened my interest in biology.*

Jewel Plummer Cobb, Biologist

*President and Professor Emerita of
Biological Science
California State University at
Fullerton*

We also spoke with women who had at some point attended an all-female high school or college, and others who had attended or worked at historically black colleges or universities. Many recalled these environments as being particularly supportive or encouraging, with the lack of men or white people around, they were able to develop their talents and leadership skills without having to contend with sexist or racist resistance and discrimination.

Until I came to Howard, I had never been in an environment that was mostly black. The state college and the community of Petersburg, Virginia were also predominantly black. For the first time in my life my race was not the first thing people noticed about me. It was wonderful to be in situations where there were a lot of black people, especially black women.

*Esther A. H. Hopkins, Chemist,
Lawyer
Deputy General Counsel
Massachusetts Department of
Environmental Protection*

Almost everyone has a mix of positive and negative experiences as they grow up and move through life, but another crucial variable in determining who will succeed is the way people react to the negative experiences they do have. And when negative and discouraging forces are as pervasive as they are for most women in our society, how one reacts to them can make a crucial difference. Obviously none of the women in our book responded to discouragement in their lives by leaving science or engineering altogether, although a few did switch specialties.

One day I rebelled and announced that I was going to be an engineer. My mother turned green and said "You can't do that; no one will marry you." When I told the school guidance counselor the same thing, his answer was, "No one will hire you; that's not a job for women." I resolved at that moment that someone would hire me because I was going to be a very good engineer.

*Eleanor Baum, Electrical Engineer
Dean of Engineering
The Cooper Union*

/Many women who encountered discrimination or discouragement didn't notice or register what was going on at the time, or else didn't find it discouraging or frustrating. Other women, faced with such difficulties, simply decided to pretend that the difficulties weren't there, or to actively ignore them; others chose to persist despite it all; and many used challenge as motivation, and responded to roadblocks with stubborn defiance. Some simply decided that they wanted to do whatever it was they were being told they couldn't do. Regardless, there is no doubt that some women succeeded in the face of enormous obstacles simply by being tough, stubborn, and persistent, and sometimes by being openly rebellious.

My adviser wasn't supportive of careers for women; he was upset when I received fellowship support because he believed that women shouldn't be supported for graduate school because they would never contribute much to their fields. I stayed away from him as much as possible! He wasn't a serious obstacle, I simply plodded along hoping for a chance to do what I wanted to do.

*Mildred Dresselhaus, Physicist
Institute Professor of Physics
Massachusetts Institute of
Technology*

Almost all of the women at some point faced the loneliness, frustration, discouragement, or self-doubt that often results from the relative isolation of women in science and engineering or general discrimination against "outgroups" and sexism. While the inherent ability to shrug off or rebel against unfairness is helpful, many women are able to persist in the face of adversity because they learn how to seek out or create situations where they have supportive interactions that bolster their confidence and feelings of self-worth.

There have been times when I've gone out in the field on a project, and when I showed up the people looked at me as if to say "Surely you jest." I simply tell them that the packaging is incidental. It helps that I grew up on a farm and am used to working with my hands. Once I show people that I can carry my own weight they tend to forget the physical traits that they might see as barriers.

*Rhea L. Graham, Geologist
Director of the Bureau of Mines
U.S. Department of the Interior*

Some found support within their profession by creating or joining professional networks. Those could be anything from a woman in a relatively obscure subspecialty creating an electronic mailing list and newsletter to keep colleagues from geographically remote locations in touch with each other, to creating a similar mailing list for all scientists from a particular minority group to discuss common problems and difficulties. Along the same lines, many women found it useful to participate in groups for women in science and engineering, which again allowed an opportunity to compare notes, share advice, and work towards common solutions to common problems. These groups are not a panacea, and their usefulness to individual women varies considerably depending on both the group and the woman, but for many they provide crucial support.

Many women took the initiative of starting groups for other women, or serving as a resource for younger women. Assuming these kinds of leadership responsibilities helps individuals in many ways. Modeling self-respect and self-reliance for others is a great way to help oneself actually feel it. And knowing that things might be just a bit easier for those who come after can provide a good source of satisfaction and hope.

Organizations such as the Society of Women Engineers (SWE), the Association for Women in Science (AWIS), and the American Association of University Women (AAUW) have also provided much support and guidance as I progressed through my career. I've received a lot of practical advice on how to handle tricky situations from many women in these organizations. SWE and AWIS in particular, also provide a safe place to develop and enhance managerial and leadership skills.

*Patricia Eng, Nuclear Engineer
Senior Transportation Project
Officer
U.S. Nuclear Regulatory
Commission*

Women find other forms of support outside the professional environment. Many of the women we interviewed credited their spouses or partners with providing essential support for their careers, in the form of everything from being the at-home spouse, to helping with child care, to being willing to relocate for their careers, to cheerleading and emotional support. Mothers, especially single mothers, often spoke of the patience, tolerance, and flexibility of their children, as well as the support and encouragement that children could provide. Others spoke of help from their own mothers.

I believe that family history has a real impact on future life. My mother and Jim's mother worked, so we both expected women to have careers and families. Furthermore, because Jim grew up in a family with four boys and a working mother, he was used to doing domestic chores. This has been very important to our marriage.

*Linda Huff, Chemical and
Environmental Engineer
President
Huff & Huff, Inc.*

Other women talked about the importance of having supportive friends to talk to during a crisis. This came up especially in the context of dealing with the frustration, anxiety, and self-doubt that accompanies sexual harassment.

I was fortunate to have women friends in other fields to talk to who could reflect back to me my strengths.

*Priscilla Auchincloss, Experimental
High Energy Physicist
Research Associate, Department of
Physics, and Director, Program for
Women in Science and Engineering
University of Rochester*

Finally, some women developed specific strategies for difficult interpersonal interactions. Some said they'd learned to pick their fights carefully and not waste their energy on battles they were unlikely to win, or to which they couldn't sustain a strong commitment. Others learned to use humor constructively to point out to colleagues when they were behaving in unfair or inconsiderate ways. Others became proactive about walking into situations and announcing, "Yes, I'm a woman; so what? Let's get to work."

I view myself as a businessperson first who happens to be an engineer and happens to be a woman. I've stood in front of many groups consisting of men who are often older than I and said, "I stand before you born into female-type package. DuPont is not paying me or you for the package; rather they are paying us for how we use the gray matter between our ears."

*Deborah Grubbe, Chemical
Engineer
Director of Engineering*

*E.I. DuPont de Nemours &
Company*

If there is one universal constant among these women, it is that they have found ways to make their science and engineering careers part of their lives. And while each woman found the balance in a very different place, we found in their stories the satisfaction they found in being able to make their careers an integral part of a balanced, contented existence. We live in a society that has traditionally kept work and home strictly separate, and encouraged compartmentalization of individual lives in many other ways. Some people are very happy living with the dualism and enjoy having crisp boundaries between various parts of their lives. Others choose to create an integrated, continuous whole; while still others work best with a mix of dualism and integration in different areas.

On occasion I have found myself walking with my partner hand in hand on a moonlit beach, listening to the waves lapping on the sand, sipping champagne, and discussing why tailpipe temperature on pressurize relief lines are not necessarily the best indicator of a system leak (the instrument could be faulty)! I may not be terribly romantic, but somehow I find it acknowledges that I am a whole person—an engineer and a woman.

*Patricia L. Eng, Nuclear Engineer
Senior Transportation Project
Officer
U.S. Nuclear Regulatory
Commission*

There are many areas in which women seek integration in their lives, and sometimes it is as simple as finding work that allows them to bridge various interests. Some women, for example, spoke of feeling pigeon-holed in graduate school and started doing interdisciplinary work after graduation; others spoke of the value of collaboration with colleagues in different disciplines. Numerous women have found satisfaction in migrating from specialty to specialty as their interest led them, and still others found that integrating a non-science interest into their work provided the crucial relevance to the “real world” that they wanted it to have. This could involve anything from working on relevant activist causes such as the environment, public health, or women’s health to improving education for women or other minorities to making support for other women in science and engineering an integral part of their work.

Women often choose problems that are relevant to the real world, and such problems in science are often interdisciplinary and less likely to fit the classical ways science disciplines are defined.

*Debbie C. Crans, Biological
Chemist
Associate Professor of Organic
Chemistry
Colorado State University*

Almost every woman had something to say about integrating her career with her personal life and/or family, and we were struck by the wide diversity of satisfying options they had created. Some women chose to stay single and dedicate themselves to science, finding their primary satisfaction in their work or other pursuits. Some had partners, but chose not to have children; others found partners who could follow their careers and/or assume primary care of children. Some women chose to devote their primary attention to their spouses/partners and/or children, and allowed their careers to take a back seat either permanently or for a period of time. Many women spoke of relying on hired help and/or extended family to take care of their homes or children, freeing their time for other things. Regardless, it was very clear that many of these women had made a clear and conscious choice about the relationship between their work and their personal lives, and equally clear that while every option is right for someone, no arrangement works for everyone.

I decided early on that I wanted to do science, not "tag-along" science. I didn't want my career to be determined by having to accommodate to someone else. I have remained single, dedicated to science, and very happy with my life.

*Elizabeth Jones, Biologist
Professor of Biological Sciences
Carnegie Mellon University*

Working women need to develop a long-term perspective: Children may require your concentration for fifteen years or so, but then we still have twenty years of productive life after the children grown and gone.

*Jane Dillehay, Biologist
Dean of the College of Arts and
Sciences
Gallaudet University*

Many women discussed the importance of having hobbies or other interests outside of work and family. While this was certainly not the case for everyone we spoke with, many women made it clear that they had other pursuits that they regarded as quite important; these ranged from dance to musical performance to athletics to travel to an involvement in theater. Most of those women found that their other interests helped them bring a better, fresher perspective to their jobs.

We found a pervasive theme among the women of needing or wanting to be useful to society or the world. Many made links between their personal ethics, morals, philosophy, or religion and their approach to their work. While for some their work is merely a job, however interesting or fulfilling, others explicitly view their vocation as service to a greater good.

The title of our collection of stories states that there are no universal constants to describe the ways in which women find their place in science and engineering. Finding "universal constants" — unchanging, unified, observer-independent facts — is often considered the ultimate goal of science. By using the subtitle "No Universal Constants," we are not challenging the search of universals, but pointing out that there are no set patterns that a woman might follow in becoming a scientist or engineer. Yet, as we look at the lives in *Journeys*, two aspects do stand out — passion for the work, and a belief in one's own ideas.

My first love is the outdoors—I enjoy mountain climbing, backpacking, hiking, canoeing, swimming, and bicycling. Many of these interests I inherited from my parents who, at age eighty-three, are still hiking and backpacking. I am at home in nature, and when I can't be out in the wilderness, I can often be found in my garden at my home in Austin. That's the real me. My day-to-day life is something very different.

*Karen Uhlenbeck, Mathematician
Professor and Sid W. Richardson
Foundation
Regents Chair in Mathematics
University of Texas at Austin*

Quite a lot has been written about women and men who left science because the existing paradigm or institution did not accept their ideas. In the case of men, however, until they speak their ideas, no preconceived sense of disqualification is conveyed by the

institutional milieu. Women, by their very being, may provoke this sense of disqualification from those who make up the institutions. The women in JOURNEYS were those whose internal passion and belief in their work inspired them to go forward despite obstacles: they planned their own journeys; they realized their own dream.

What's motivated me all along is that I fundamentally enjoy what I'm doing, and I'm good at it.

*Frances Lockwood, Chemical
Engineer
Vice President of Technology and
Product Development
Valvoline*

The lesson for those of us in a position to advise is to pay attention to the critical importance of internal validation, to help our students believe in their core answers and values; we need to support them as they develop strategies to work their own way, not by imitating, but by acquiring the best possible preparation to blaze their own trail.

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