SCIENCE EDUCATION

The Pipeline Is Leaking Women All the Way Along

Monica Healy always had a flair for mathematics. As a child growing up in the suburbs near Washington, D.C., she liked math and consistently did well in math classes, scoring in the exceptional range on standardized tests. Given that kind of aptitude, Healy seemed to be cut out for a career in some kind of science. But that wasn't the way it turned out. Instead, several obstacles intervened and sent her down a different path.

One of those obstacles has to do with how society views girls and science. It's not necessarily a positive view: The nuns in Healy's all-girl Catholic school didn't even teach science. As a result, says Healy, "I really couldn't imagine doing anything useful with math." That obstacle was removed when she got to high school and began taking chemistry and biology (along with math, in which she continued to excel).

Yet there still was a problem, one that has to do with how women view science: The science courses seemed dry and lifeless. That continued to be true for Healy at the University of Maryland, where her remaining interest in science vanished. In college, the conclusion that had been there below the surface all along became conscious and Healy decided she was a "people person." The students she knew who were majoring in science, she says, "were so dedicated to doing science that they didn't seem to have room for people in their lives."

Today, Healy, 43, remains very much a people person. She is staff director of the U.S. Senate Democratic Policy Committee, where she works on ways of reforming the nation's complex, out-of-control health-care system. In her work, Healy uses the analytical skills she developed in math class, but her work has far more direct relevance to human concerns.

The story of Monica Healy raises questions for science education, because there are many Monica Healys in this country: bright women with scientific aptitude who get diverted into other careers along the line. As a result, women are seriously underrepresented in the ranks of scientists and engineers. Women make up 45% of the U.S. workforce, but they account for only 16% of employed scientists and engineers. Though women earn more than half the bachelor's and master's degrees and more than a third of doctorates awarded at U.S. colleges and universities, in science and engineering disciplines they receive only 30% of bachelor's degrees and less than a quarter of advanced degrees. And those dismal statistics would look even worse if the figures for one traditionally "feminine" field—psychology—were removed.

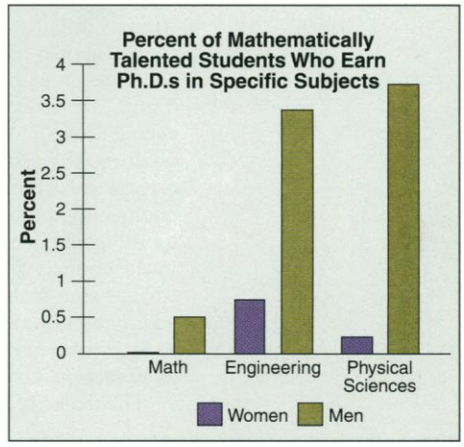
"The pipeline is leaking women" is how Sue V. Rosser, director of women's studies at the University of South Carolina puts it. "And unless this country does something to plug those leaks, women will continued to be denied opportunities in rewarding, high-paying careers and this country is going to be worse for it."

Over the past 15 years dozens of studies funded by public agencies, private foundations, industry, and schools have pinpointed factors that drill holes in the pipeline. One is that—Monica Healy to the contrary—fewer girls than boys have the confidence that they can master math. But many of the other factors reflect the kind of science culture that caused Healy to lose interest: outmoded stereotypes, an emphasis on scientific knowledge independent of real-world uses, and an image of scientists as obsessed with science to the exclusion of other human endeavors. Yet, as a potpourri of innovative programs shows, these conditions can be changed (see story on page 412).

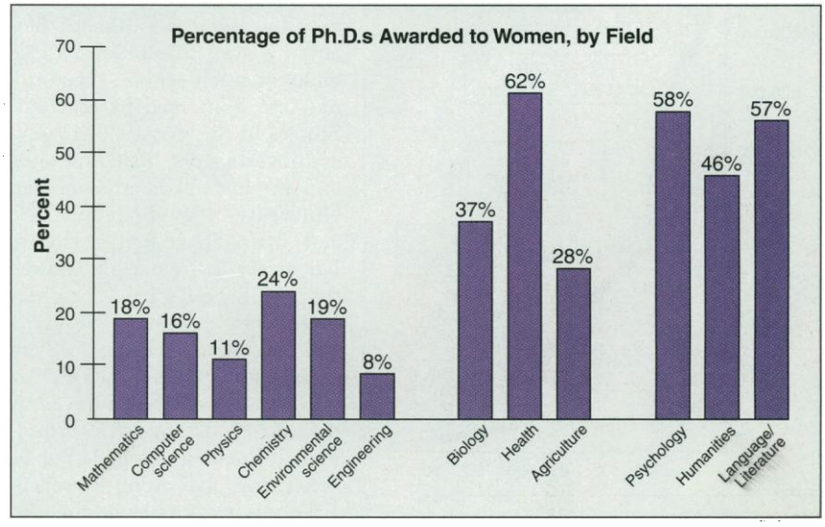
The culture of science fails to attract women who might otherwise become gifted scientists.

Those changes may not come so easily, though. One subject that shows how tough the work of change will be is mathematics. A chief deterrent to later success in science and engineering is the poor preparation in mathematics most women receive in high school. The reasons for this difference have touched off some of the hottest controversies in the field of science education. Some researchers argue that the difference is due, at least partly, to innate disparities in mathematical abilities. The proponents of the "innate abilities" argument, among them Camilla Persson Benbow and David Lubinski, codirectors of the Study of Mathematically Precocious Youth (SMPY) at Iowa State University, contend that the disproportionate number of males in advanced math classes in high school reflects underlying gender differences.

Much of the basis for these claims stems from differences in the distribution of scores on the math section of the Scholastic Aptitude Test (SAT-M). On the whole, young women score at least as well, and perhaps slightly better, than young men on the SAT-M. Yet the distribution of scores differs sharply according to gender: The curve for men is more spread out, so that at the lowest—and highest—levels there are more males than females. Because most scientists are drawn from those with the highest levels of math preparation, "the effects of



It's not math anxiety. Even among the most mathematically gifted students, far fewer women than men pursue science careers.



Fielder's choice. The proportion of women getting advanced degrees varies enormously by field—from less than 10% in engineering to more than 50% in psychology.

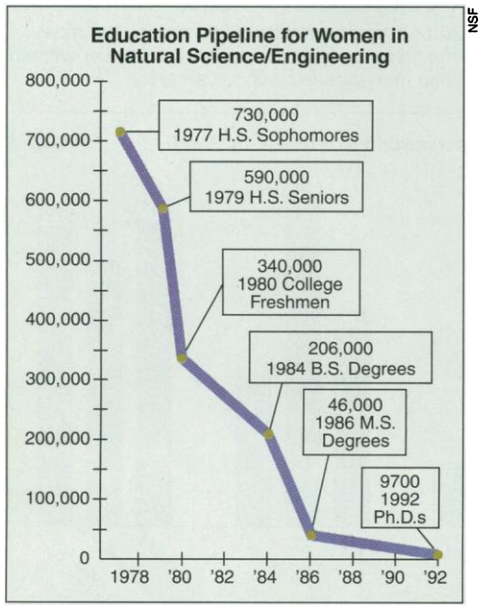
these disparate ratios for the math-science pipeline is clear," says Benbow. "A greater number of males than females will qualify for advanced training in disciplines that place a premium on mathematical reasoning."

In addition, the SMPY researchers have found that differences in values between boys and girls reinforce the apparent differences in capacities at the very highest levels of mathematical performance. On a battery of tests, males scored higher in preferences related to abstractions and theory, while females scored higher on social values. "What we're measuring here is related to one of the biggest differences between genders, namely that of 'people versus things,'" says Benbow. "Females tend to be more interested in the former, males in the latter." In some instances, this will lead women to specific fields, says Benbow: "Females tend to go into more organic sciences, such as biology, medicine, and psychology, while males go for the more inorganic fields, such as physics and engineering." But in other cases these preferences can drive women out of science.

Critics of the "innate abilities" school aren't buying the idea that these differences are intrinsic. "These studies have big holes in them," says Rosser. The critics have no argument with the notion that women prefer fields involving people rather than abstractions. They strongly dispute the hypothesis, however, that this is an innate, gender-based preference.

To begin with, says Rosser, the Iowa State program looks only at extremely high math achievers, which account for a mere 1% of college-bound students. "In addition, the results of so-called interest tests depend on how you word the questions. Males are interested in engineering problems no matter what, but women respond more energetically when these problems are put in the context of helping people or the environment." It's not that women aren't interested in engineering, adds Rosser, it's a question of context: "Women aren't so interested in engineering as a technical matter, but as a practical matter."

The majority of those who have studied the issue of gender preferences as they relate to science argue that culture, rather than biology, points women and men in different directions. Almost from birth, society sends girls and boys different messages about their abilities and expectations. Once children reach school, those signals are reinforced by teachers. Studies in the mid-1980s by several investigators, including Myra and David Sadker at American University in Washington, D.C., and Charol Shakeshaft, at Hofstra University in New York, showed that math and science teachers make more eye contact with boys and pay more attention to them than they do to girls in their classes.



Downer. The drop-off in the study of science among women is extremely steep from high school through Ph.D.s.

That disparity is reinforced by the teachers' differing styles of dealing with male and female pupils. When boys give wrong answers in class, teachers challenge them to find the correct answer; girls get sympathy. Even in group activities designed to provide a level playing field, girls may get short shrift. "Boys tend to operate the equipment and actually perform the experiment while girls tend to record data and write reports," says Patricia B. Campbell, director of Campbell-Kibler Associates, a science education consulting group. "This reinforces a boy's self-confidence, while eroding that of the young girl."

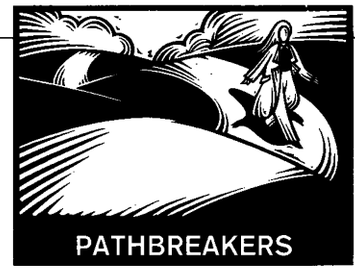
In fact, a loss of self-confidence—rather than any differences in abilities—may be what produces the first leak in the female science pipeline. That leak begins around the seventh grade and continues through high school. Helen Astin and Linda J. Sax of the University of California, Los Angeles (UCLA), studied seventh-graders and found an interesting difference. The difference wasn't in performance—males and females performed comparably in math and science courses—but in the fact that females consistently underestimated their abilities. Because of this lack of confidence, the females begin taking fewer math and science courses than their male schoolmates, a trend that accelerates in high school. "By the time these young women graduate high school," said Sax, "they have taken so many fewer math and science courses that it precludes significant numbers of them from pursuing college science and engineering majors."

Indeed, the effects of taking or not taking math and science in high school reverberate through a person's career, as the UCLA researchers found in a later study of 15,050 first-year students at 192 4-year colleges and universities. In that study, 21% of men but only 6% of women reported they would major in science and engineering. Among the biggest factors that helped women stay in science and engineering were the number of physical science courses taken in high school and higher confidence in mathematical skills.

One of the notable findings by the UCLA researchers was that women who attended smaller, more prestigious schools had the biggest decline in self-confidence—and the highest dropout rate. "The intense competition at these schools and the greater degree of contact with faculty were actually discouraging factors except in situations where there were large numbers of women students," says Sax.

The conclusion drawn by many researchers is that the presence of other women—creating a different environment from the competitive male domain of most science—is a key ingredient in women's success. And women's colleges do have a higher retention rate for female science majors than mixed schools. But the presence of other women may be only one factor. Another could be that women's colleges are designing programs specifically for women. "All our science classes, but particularly the introductory ones, are structured around cooperation, hands-on learning, and relevance to real-world problems," said Leona Truchan, professor of biology at Alverno College, an all-women's school of 2500 in Milwaukee. "This shows our women that they can do science. It gives them the self-confidence to continue on when their coursework gets tough. As a result, we have a very high retention rate."

The same principles—cooperation and hands-on work—have helped transform chemistry, traditionally one of the worst disciplines at retaining women students, at all-female Wellesley College in Wellesley, Massachusetts. "Our chemistry department totally revamped itself, from the design of its courses (they're



A Thoroughly Modern Marriage

It's not exactly unheard of in science for a younger woman to marry an older, better established scientist in her discipline—often one who has served as her mentor—and thereby benefit from his experience and advice. It's not so often, however, that it happens the other way: a marriage where the wife was the mentor and senior scientific partner. But that is the case for geologists Diana and Bob Kamilli. "People are amazed at our sort of role reversal," says Bob, a 45-year-old economic geologist with the U.S. Geological Survey (USGS) in Tucson, which has its offices at the University of Arizona.

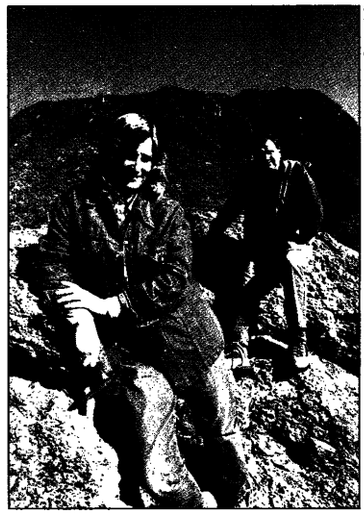
The Kamillis' unusual two-career marriage has now lasted 23 years and the couple has had to be flexible enough to survive some setbacks. Perhaps the most serious was when Diana failed to win tenure at Wellesley, where she had been chair of the geology department. They have survived, however, and both say their lives are rich and they are pleased with the way their careers have developed —even though, as Bob says, "we don't expect to be elected to the National Academy of Sciences."

Bob says he is proud of the fact that Diana, 51, was "most definitely my role model." She was 5 years ahead of him in science when they met in introductory geology at Rutgers University, where Diana was a graduate student lab assistant and Bob was an undergraduate. She was impressed with him as a student, and played an important role as a mentor: "She introduced the idea to go to grad school," says Bob. "In my family, I was the first generation to go to college."

By the time Diana earned her Ph.D. from Rutgers in 1968, the pair were planning careers in tandem. Diana taught geology at City College in New York while Bob finished his bachelor's degree and applied to graduate schools. Then, at 26, Diana was offered the chair of Wellesley's tiny geology department, and Bob was accepted at Harvard; they got married and moved to Cambridge.

After 6 years at Wellesley, Diana was denied tenure, partly, she thinks, because her mentoring activities—teaching, taking students on field trips, and running the department—left her little time to publish. She recovered by adapting her training to a different scientific niche. She and a colleague received a National Science Foundation grant to do research in archeological geology through both Harvard and the Massachusetts Institute of Technology. Having learned the importance of publishing the hard way, she published extensively on the composition and provenience of Mesopotamian potsherds, helping strengthen a theory that the pots were made by traveling potmakers, who used local materials rather than carrying the pots with them along well-known trade routes.

Meanwhile, Bob had finished his doctorate and accepted an offer with Climax Molybdenum Co. in Colorado. "It was his turn," says Diana. They moved to Colorado, where she tried archeological consulting—analyzing artifacts and materials at archeological sites. When he had a chance to join the USGS in 1983—in Saudi Arabia —the pair decided to go. "I was off the job ladder, and we had a child by then, so it was a good excuse to take time off to be a parent," says Diana. When they returned to the United States in 1989, Diana re-established her consulting business.


TOM IVES

Role reversal. Geologist Diana Kamilli was mentor and senior role model for her husband, Bob.

It's worked out so well Diana says she sometimes feels her unusual job strategy is "cheating." "Deep down, I sometimes feel I should have a more structured job, with my training." But, she says, "I don't think this would work if we both wanted structured jobs. This way, I can do science fairs with my daughter, feed the kids' rats, and work at the microscope." And those are all things Diana Kamilli expects to keep on doing, thanks to some unusually flexible roles.

–Ann Gibbons

actually harder but provide more cooperative and hands-on experiences) to the way the faculty interacts with the students," said Paula M. Rayman, director of Wellesley's Pathways for Women in the Sciences program and an associate professor of sociology. "It's the model department here." As a result, says Rayman, women not only stay in chemistry but frequently switch into the program once they begin taking chemistry classes.

Keeping women in science through college isn't necessarily enough, however. Although Wellesley's retention rate among science majors is higher than the 53% achieved by its neighbors Harvard and Radcliffe, a survey of recent graduates turned up a surprise: 20% dropped out of science within 6 months of graduating. "This was a shock," said Rayman. "We know the attrition rate is high after college, but we didn't expect that the biggest drop would occur almost immediately, before getting to the so-called chilly climate of graduate school."

Rayman found some factors that predict who's going to go on in science after leaving Wellesley, such as having had experience in a faculty member's lab. Yet it's hard to escape the conclusion that the culture of science itself may also have something to do with women's lack of interest in pursuing a scientific career.

"One of the characteristics of the ideology of science is that science is a calling, something that a scientist wants to do, needs to do above all else and at all costs," says Sheila Tobias, a consultant on science education with the Research Corp. in Tucson. "Another is that both scientific talent and interest come early in life—the 'boy wonder' syndrome. If you don't ask for a chemistry set and master it by the time you're 5, you won't be a good scientist. Since far fewer girls and women display these traits than boys and men, you end up with a culture that discriminates by gender."

Tobias argues that until the culture of science is rethought from the ground up and scientists begin to change their notions of the preferred behavioral characteristics of a scientist there will continue to be high dropout rates for women. "The next step is to have some self-examination by the scientists themselves as to what a scientist really is," Tobias says. Until such a reexamination takes place, the best alternative will be programs that aim to provide the kind of environment in which science seems a natural thing for a woman to do.

–Joe Alper