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1 The science career pipeline

In this chapter we discuss the 'pipeline' thesis for improving women's participation in science. This 'supply side' approach assumes that if sufficient women are encouraged to enter the scientific and engineering professions, the gender gap in science and technology will disappear.

The scientific career track, from elementary school to initial employment, has been depicted as a 'pipeline' like those for the transport of fluids and gases such as water, oil or natural gas. The rate of flow into scientific careers is measured by passage through transition points in the pipeline such as graduation and continuation to the next educational level.

Nevertheless, the flow of women into science is through, 'a pipe with leaks at every joint along its span, a pipe that begins with a high-pressure surge of young women at the source – a roiling Amazon of smart graduate students – and ends at the spigot with a trickle of women prominent enough to be deans or department heads at major universities or to win such honours as membership in the National Academy of Science or even, heaven forfend, the Nobel Prize' (Angier, 1995). Even this negative depiction of the pipeline as a leaky vessel is too optimistic. As we shall see, many women are discouraged from pursuing their scientific interests far earlier in their educational career than graduate training.

Although the rate of women entering scientific professions has improved significantly, especially in the biological sciences, the numbers reaching high-level positions are much smaller than expected. In the United States, for example, decades after the science-based profession of medicine experienced a significant increase in female medical students (currently about 40% are women), only 3% of medical school deans and 5% of department heads are women. Dr Eleanor Shore, dean for faculty affairs at Harvard Medical School, recalled, 'Originally we thought if we got enough women in, the problem would take care of itself' (Angier, 1995). But it obviously has not.

Significant numbers of women enter the 'pipeline' and then leave at disproportionate rates, or function less effectively, as covert resistance to their participation creates difficulties. At best, the picture of women's participation in science in recent decades is mixed. Indeed, the pipeline analogy is unintentionally appropriate as an implicit criticism of the way that the recruitment to science takes place.

In addition to the positive meaning of steady flow and assured delivery, a pipeline also connotes a narrow, constricted vessel with few if any alternative ways of passage through the channel. At each age grade, the entry ways for women become narrower and increasingly restrictive. As more are excluded, the talent pool for the next level to draw upon becomes smaller.

Although the genders are almost equally represented in the early stages of the pipeline they increasingly diverge at the later stages, resulting in a much smaller proportion of women than men emerging from the pipeline. At the point of career choice, many women are diverted from the academic and research tracks, even though some who are trained as scientists pursue science-related careers such as scientific writing or administration. The U.S. science pipeline runs through a distinctly different educational landscape than its counterparts in many other countries, and it is worth taking a moment to describe the system here.

THE U.S. EDUCATIONAL SYSTEM

In contrast to most European, Latin American and other countries where a specialized course of study on one or a few related areas makes up virtually the entire undergraduate curriculum, the U.S. educational system does not expect students to make an early choice of careers. Even though an increasing number of secondary and even middle

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schools have occupational themes such as healthcare, art and science, all offer a general education. The flexibility of the U.S. undergraduate degree allows room for secondary education to remain unspecialized.

Students typically graduate from high school after twelve years of primary and secondary education at the age of seventeen or eighteen. Where to go to college or university becomes a serious issue in the third year of high school, although student and parental anxieties about getting into a prestigious college or university have pushed these concerns ever earlier. Again in contrast to countries with national systems of examinations at secondary school leaving, the U.S. high school offers an education that can vary widely in quality among schools and even within the same school. High school is still the quintessential U.S. social scene depicted in television programs and motion pictures of a youth culture focused on peer status, looks and athletic ability. Intellectual merit is not a leading status distinction except in a very few leading public and private high schools.

Universities also vary widely in quality of education and prestige, in contrast to Europe where university-level institutions are, more or less, expected to be on the same level. There is also a tradition in the U.S. of students going to university away from home, if it can be afforded. This makes the college decision a major turning point in life. It also marks the entry of the student into a nationwide educational and prestige gradation market. To take account of the wide differences in quality among secondary schools, an external system of exams offered by a non-profit corporation rather than a government agency was established in order to help universities sort potential students from a wide variety of backgrounds. Once university intake broadened from a select set of students attending college preparatory public and private high schools, as had been the case in the 1920s, to a mass education system, uniform measures were needed and the College Board examinations were established for this purpose.

The College Board examinations focus on general abilities in mathematical and analytical reasoning and are not directly tied to the high school curriculum. Therefore, a separate educational industry has grown up offering courses and tutoring to prepare students for these examinations, whose sponsors persist in insisting that formal preparation will do no good. Through these exams, high school grades, recommendations and sometimes an essay to be written on 'life goals', 'the most influential book I have read' or some such topic, combined with interviews by an alumnus or a college admissions officer, an initial selection is made.

High school graduates are sorted into more than 3,000 institutions of higher education, ranging from four-year baccalaureate colleges to universities offering Ph.D. degrees. However, this selection is still malleable since college students increasingly take time off from their studies to travel or work for a while and then decide to apply for transfer.

Almost 70% of U.S. high school graduates now continue on to post-secondary education. This is still in sharp contrast to the U.K. which has only in the past decade seen a rise from 10% to 30%, with an expected rise to 40% of secondary school leavers continuing on to university during the next decade.

In the U.S., general education continues from high school into the university. 'Distribution requirements' insure that students take one or more courses in the various spheres of knowledge such as science, art, history, languages and mathematics. In addition, many colleges and universities require students to take certain courses, typically in writing and the history of western civilization, as part of a general education program. In other countries such broad knowledge and skills are expected to be acquired in secondary schools, leaving the university career completely to specialized and professional training.

In the U.S. specialization begins at the baccalaureate level with declaring a major. 'A major' is a group of related courses in a disciplinary area such as history or biology, although it can also be an interdisciplinary group of courses in an area such as biology and society. An individual course typically consists of a sixteen-week series of class meetings totalling around three hours per week. It

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may combine lectures, class discussion and laboratories. Evaluation is likely to be some combination of laboratory exercises, short examinations or quizzes, a mid-term examination and/or a final examination. A research paper may also be required.

The course is the basic building block of undergraduate education and the credits attached to it, typically three or four, are added up to the requisite 120 for the degree with the major representing perhaps a third of that total. The European model would instead be the degree course with a set of requirements, lectures and examinations geared to measuring an end result rather than discrete pieces along the way, through the course.

The science major in the U.S. follows an intermediate format between the general U.S. undergraduate and specialized European educational models. Its courses typically must be taken in sequence and a larger proportion of the student's time is required. This leaves less time for electives, those courses apart form major, distribution or general education requirements in which students may follow a non-degree interest or simply take a course that has a reputation for being interesting, easy or challenging, whatever meets their needs!

Vocational choices can be put off at least until the second year of a four-year undergraduate career, or even later, unless one is in the sciences. Even if a science or engineering major is chosen late in the undergraduate career, courses can be made up in summer school or by taking an extra year for the degree. Some universities even offer a post-baccalaureate year program to prepare humanities and social science majors who have decided after graduation that they wish to go to medical school, a post-bachelor's degree program in the U.S. A year of chemistry, biology, physics and other related courses allows them to meet the basic requirements for admission.

The U.S. undergraduate model of education, based on courses, continues on into graduate school. A Ph.D. program typically begins with a set of courses during the first and second years whose purpose is to bring everyone up to the same level of basic knowledge in the field. Now, at this late stage, the U.S. system finally begins to follow the

European model, by evaluating students through an extensive 'qualifying' examination, cross-cutting an entire field.

Indeed, students do not necessarily have to prepare for the qualifying exam, the prerequisite for beginning research for the Ph.D. dissertation, by taking a set of courses. They may also study on their own, using reading lists, or more likely, in small groups of fellow students, so-called study groups, where old exams and problems are discussed. Again, this organized system of preparation for research is in contrast to the traditional European model in which a student tackles a research problem from the outset of the advanced degree process. There, the problem is often set in advance and candidates are advertised for in the scientific press.

Although the U.S. secondary and undergraduate education varies greatly in quality, it is at the graduate level that the U.S. excels. Research groups of a professor with graduate, undergraduate students and technicians are the basic building block of U.S. academic science. Assistant professors in the U.S., who would be junior researchers under a professor in many European countries, have the responsibility for raising their own research funds through competitive grants to start their own group. Success or failure in convincing the research community to fund their proposal is the prerequisite for attaining a permanent position in a U.S. research university. However, as we shall see, women and men experience the various stages and phases of this system quite differently.

THE LOSS OF WOMEN TO SCIENCE

With this system of education in mind, we return to the 'pipeline' hypothesis. This optimistic hypothesis has been at least partially disconfirmed by the mixed experience of the most recent generation of women in science and engineering. True, a large number of women in the U.S. major in science and engineering and a significant percentage of women receive BA degrees. As a result, the proportion of science and engineering bachelors' degrees going to women has almost doubled in three decades, rising from 25% in 1966 to 47% in 1995 (NSF, 1998:

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171). But the number of women enrolled in graduate school is still significantly lower, at 38% in 1995 (ibid.:226–7). And the percentage who emerge with a Ph.D. in these disciplines is lower still, reaching only 31% by 1995. Even this figure is misleading, however, since it conceals sharp contrasts by discipline. Most of the progress is attributable to the greater presence of women in the life and social sciences, in contrast to the physical sciences and engineering. Highly unequal participation is still the norm in many fields.

These contrasts are, not surprisingly, most evident at the highest academic levels. Starting from what was then a relatively strong base of 16% in the 1960s, women increased their representation among Ph.D. biologists to 40% by the 1990s (see Table 1.1). From a smaller base of 7%, chemistry has seen a corresponding rise to 27%, while the geosciences increased more dramatically from 3% to 22% in the same period. However, although mathematics, physics and engineering have also seen substantial gains in the presence of women among doctorates, in none of these fields did the 1995 figure even reach one in five. Thus, starting from bases of 5% in mathematics, 2% in physics, and less than 1% in engineering in the 1960s, the proportion of Ph.D.s going to women has risen to 19%, 12% and 11% in the 1990s.

Table 1.1 *Women's share of science and engineering Ph.D.s, 1966–1997*

	1960s	1970s	1980s	1990s
Biology	16	21	33	40
Chemistry	7	10	19	27
Geosciences	3	6	16	22
Mathematics	5	10	15	19
Physics	2	4	8	12
All engineering	<1	1	6	11

Source: U.S. National Science Foundation, Survey of Earned Doctorates.

EUROPEAN COMPARISONS

Most European countries have shown similar patterns to the U.S. For example, in the United Kingdom, the starting point was so low in most fields that, even after some progress, women remain far below parity. In the late 1980s, female chemists in the U.K. were 35% of undergraduates, 24% of graduate students, 22% of post-doctoral researchers, 5.5% of lecturers, 1.5% of senior lecturers, 1% of the readers and 0% of professors. In U.K. academic science as a whole only 3% of professors and department heads were female, compared with 10% in the U.S. In France, there is a decreasing proportion of women physicists at the higher levels of government-sponsored research institutes (CNRS). At the lower levels, 42% of the best-qualified research assistants are women, perhaps in part reflecting their disproportionately low (16.8%) representation (Couture-Cherki, 1976).

The paucity of women in high-level scientific positions in the U.K. is exemplified by a footnote identifying the author of a preface to a volume on the condition of women in science: it notes that Professor Jackson was the first and only female professor of physics in the United Kingdom (Haas and Perucci, 1986). She is now deceased, but there were two female physics professors in British universities in the early 1990s (Healey, 1992). Nevertheless, the continuing low participation at higher career levels is a virtually universal cross-national phenomenon despite a history of improvement at the lower levels. University College London is a bright spot. The proportion of female professors at 9% is three times the national average. This is due to 'attention to problems of family and childcare'. Despite the bleakness of the overall situation, this instance demonstrates that actions can be taken that will significantly improve matters.

THE FALLACY OF THE 'SUPPLY SIDE'

The expectation that the problem of participation of women and minorities in the scientific and engineering professions could be solved with a bit of 'pump priming' is a supply side thesis. The supply side

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approach is codified in the so-called 'pipeline' thesis that recruiting more women is a sufficient strategy. By encouraging girls to study science, so the theory goes, participation of women and men in science will become more equal. Once this is accomplished, it is expected that one can then wait patiently for the next generation to witness women's inevitable rise to leadership positions in science in equal proportions to male scientists. Such a focus tends to neglect analysis of the 'demand side', especially organizational resistance to change and the persistence of barriers to entry of women into the scientific and engineering professions. Although there has been some recent progress, women continue to be chronically underrepresented in scientific careers, and their participation declines as one moves higher up the career ladder (Zuckerman, Cole and Bruer, 1991; National Research Council, 1993).

Role models

Some proponents of women in science believe that presenting young women entering the scientific and engineering professions with a picture of the resistance they will encounter will discourage them from going on. They believe that introducing young women to successful role models is the best way to enhance their chances of success.

A recent event hosted by the Section of Women In Science at the New York Academy of Sciences further illustrates the contradiction of celebrating the achievement of successful female scientists as an encouragement to girls to do science, rather than warning them about (and thus preparing them to meet) the possible obstacles. Several leading female scientists and engineers including Sheila Widnall, then Secretary of the Air Force, presented an account of their careers to an audience primarily composed of secondary school women, pursuing Westinghouse and other awards. Although one woman mentioned significant obstacles in her path, such as being turned down for tenure despite considerable research achievements, the overall tone of the meeting was upbeat and celebratory. The darker side of the scientific endeavor for females was played down.

As minorities move up educational and job ladders, it is expected that the problem of exclusion will be solved. However, a significant increase in women in academic science is unlikely to be realized simply by increasing the numbers of women who embark on a scientific career. Encouraging more women to enter the pipeline is at best a partial answer if so few are willing or able to come out at the other end and carry on professional careers in science.