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WOMEN, SCIENCE, AND ACADEMIA *Graduate Education and Careers*

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In the study of gender and society, science is a strategic analytic research site—because of the hierarchical nature of gendered relations, generally, and the hierarchy of science, particularly. Academic science, especially, is crucial to, and revealing of, status in science and society. This article focuses on three questions: What is the status of women in scientific careers and the role of graduate education in these careers? What are the implications for the analysis of gender? Where can we intervene, and how? In addressing these questions, the arguments concentrate on the social and organizational context of science and its relationship to gender and status.

In the analysis of gender and society, my focus is on women, science, and academia. Science comprises the eight classifications of the National Science Foundation and National Research Council: physical, mathematical, computer, environmental, life, and engineering, as well as the psychological and social sciences. In this article, science refers primarily to the first six of these fields, excluding psychology and social sciences—except where specified otherwise.

Hierarchies: Gender and Science

In the study of gender and society, science is a strategic analytic research site. This is because of the hierarchical nature of gendered relations, generally, and the hierarchy of science, particularly.¹ Relations of gender are hierarchical because women and men are not simply social groups, neutrally distinguished from each

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other; rather, they are differentially ranked and evaluated, usually according to standards of masculine norms and behavior. Science, in turn, is fundamentally hierarchical.

First, science is an institutional medium of power, with consequences for the present and future human condition. Grounded in abstract and systematic theory, science is a prototype of professional claim to “authoritative knowledge” (Fox and Braxton 1994, 374). It defines what is “taken for granted” by literally billions of people (Cozzens and Woodhouse 1995, 551), and to be in control of science is to be in control of the future (Wajcman 1991, 144).

Furthermore, science connects with powerful social institutions, especially education and the state. Mathematics, with its integral relationship to science, operates as the critical “filter” subject in students’ progression through educational levels, in the same way that Latin once operated as filter subject, when the church controlled education (see Hacker 1990). As with education, a strong connection between science and the political order points to science as an agent of power. The root is this: Science costs, and the government finances. The state, in turn, has a strong stake in science and the shaping of scientific research, and scientific attainments have been taken as gauges of national resourcefulness and prestige (Cozzens and Woodhouse 1995; Jasanoff et al. 1995, 527-31).

Finally and in keeping with its hierarchical character, science is marked by immense inequality in status and rewards (Long and Fox 1995), and the valued attributes of science—such as rationality and control—have been more ascribed to men than to women (Fox Keller 1985, 1995). Put concisely then, science is a strategic site for the study of gender because it reflects *and* reinforces gender stratification.

Academia and Science

In the study of women and science, my focus is on academia. Scientists work in numbers of employment sectors—in education, industry, federal government and the military, nonprofit organizations, hospitals, and state and local government. However, as of 1997, the majority (53 percent) of doctoral-level women in science fields were employed in educational institutions, and the vast preponderance (89 percent) of these women were in higher education-academia (Commission on Professionals in Science and Technology [CPST] 2000, Table 4-11). This is also true for doctoral-level men in science, although their proportion (45 percent) in education, compared with other sectors, is smaller than it is for women.²

Assessing women’s status in academic science is critical to an analysis of women and science, more broadly. This is because science and higher education have evolved as reciprocal developments in the United States—and to understand the one (science), we need to understand the other (academia), and vice versa. Science played a strong role in transforming the college of the early nineteenth century into the modern university, and science still shapes the American university. Briefly, the reciprocal effects have been in at least four areas (Fox 1996, 266-68).

First, from the nineteenth century onward, scientific education acted to break up the generalist, classical college curriculum that trained young men for ministry, law, or government service. Science helped introduce a "modern" curriculum of lectures, seminars, and independent work that largely replaced the classical pedagogy of drill and recitation. Second, the first doctorate awarded in the United States was in science (from the Sheffield School of Scientific Study at Yale in 1861), and science paved the way and set the model for graduate education across other fields. Third, science led the way in securing federal support for research and training. This partnership between higher education and the government began in agricultural colleges, then spread to other sciences and filtered down throughout the university. Furthermore, with federal support for research, more specialization, and the winning of autonomy in research—forces largely related to developments in science—the university became decentralized. The power to make appointments and control research funds moved from central administration to academic departments. Such decentralization has come to define the complex university in the United States (Montgomery 1994)—and decentralization is a characteristic with which we have to reckon to improve practices or shape policy for women in science, as I discuss in this article.

WOMEN IN ACADEMIC SCIENCE

Accordingly, women's condition in academic careers in science is crucial to, and telling of, their status in science, broadly (Fox 1996). Academic women have already survived barriers of selection—both self-selection into science fields and selection by institutions. They have moved through the proverbial educational pipeline. They have completed or are completing doctoral degrees and have credentials for professional work. However, the highest career attainments generally elude this select group of women. For each field in the scientific classification, except psychology, the proportions of women at the rank of full professor are meager. In half of the fields—that is, in the physical, mathematical, and environmental sciences, as well as engineering—women were just 6 percent or fewer of full professors, as of 1995.³ Only in psychology are women more than 13 percent of the full professors (CPST 1997, Table 5-1).

These observations led me to three central questions: (1) What is happening to women in scientific careers, and what is the role of graduate education? (2) What are the implications for the analysis of gender? (3) Where can we intervene, and how?

Graduate Education in Science

During the past two decades, in particular, the numbers and proportions of women receiving doctoral degrees in science have increased markedly. In the life sciences, the proportion of women among doctoral recipients increased from

12 percent to 18 percent between the 1960s and 1970s; by the 1980s, women were earning 29 percent, and in the first half of the 1990s, 36 percent, of doctoral degrees in these fields (CPST 1997, Table 2-1). In the mathematical, physical, earth, and atmospheric sciences, proportions are lower, but across these fields,⁴ women were earning 8 percent of the doctoral degrees in 1970s, 15 percent in the 1980s, and 20 percent in the first half of the 1990s (CPST 1997, Table 2-1).

Twenty years ago, observers of trends (including feminists) projected that occupational equity for women in science was a "matter of time"—time for the increasing cohorts of women Ph.D. graduates to mature and move through the ranks. However, these assumptions and beliefs that women's growing access to education would result in gender equity in scientific careers have proven unfounded. It is not clear whether women's gains in education are cause or effect of changes in other economic, social, and political roles (Fox 1995a). Increased levels of education have not necessarily resulted "as a matter of course" in progress in other areas for women (Schwager 1987, 335).⁵

Accordingly, despite the number of women with doctoral degrees earned in the 1970s and 1980s, and the passage of years allowing these women to mature in professional experience, the proportion of women who attain academic rank as full professor has not kept pace with the growth of women holding doctorates. In 1973, women were 4 percent of professors across all science fields; in 1987, that proportion was 7 percent; in 1993, 10 percent; and in 1997, still just 11 percent (CPST 2000, Table 5-1; Fox 1999a); and these figures are inflated by the numbers of women in psychology included in the classification of all sciences (see also Gibbons 1992).

Even assuming up to fifteen years from receipt of doctorate to rank of full professor, women's degrees are not translating into expected rank over time. These discrepancies are documented in mathematics, chemistry, and across numbers of fields in higher education⁶ (American Statistical Association 1993, 4; Roscher 1990; University of Wisconsin 1991, ix; Vetter 1992, 37-38).

One might ask then, despite their abilities, are women and men receiving doctoral degrees from different types of institutions, and is this a root for career outcomes? The answer is no. With some disciplinary variation, women and men are about equally likely to have received their degrees from top-ranking institutions (Fox 1995b, 217; National Research Council 1983). Across science fields, the general pattern is one of similarity in doctoral origins for women and men. Gender equity in scientific careers is not a matter of simply improving the doctoral origins of women.

Likewise, gender differences are small in certain indicators of financial support for graduate training, measured as percentages of women compared with men who had held research or teaching assistantships during graduate school (National Research Council 1983). However, these data do not specify the quality or character of assistantships and graduate training (Hornig 1987). Better clues lie in the social and organizational features of graduate education.

Organizational Context

The social and organizational context of science has been the subject of my study of doctoral education in science and engineering, supported by the National Science Foundation (Fox 1998, 2000, forthcoming; Fox and Stephan 2001). This study involves a national survey of 5,000 students and faculty members in five science and engineering fields (chemistry, computer science, electrical engineering, microbiology, and physics), site visits to 22 different science and engineering departments, and case studies (with site visits) of 10 programmatic initiatives for women in graduate education in science and engineering. The study especially concentrates on characteristics and practices of departments, research teams, and advisement in doctoral education. These encompass matters of inclusion and exclusion, nuances of training and advising, and evaluative practices as they operate for women and men. Such factors, in turn, indicate different opportunities for women and men to participate in research groups, to collaborate, and to gain significant roles in the scientific enterprise.

Organizational context is important in explaining attainments across educational and occupational areas. But it is especially important in scientific fields—with implications for the study of gender. Scientific work revolves on the cooperation of people and groups; it requires human and material resources. Compared with the humanities, for example, the sciences are more likely to be conducted as teamwork rather than solo; to be carried out with costly equipment; to require funding; in short, to be more interdependent enterprises. Compared with nonscientific fields, sciences are fundamentally “social” and “organizational” (Fox 1991).

What are the social and organizational features of doctoral education in science as they operate for women and men, and what are the consequences? My research points to different experiences and outcomes for women and men students in their departments, in their research groups, and with advisers. Figure 1 presents a summary⁷ of the experiences reported in a national mail survey of 3,300 students in chemistry, computer science, electrical engineering, and physics,⁸ conducted in 1993-94. The departments are differentiated into three categories—those relatively high, low, and improved in proportions of doctoral degrees awarded to women over a 17-year period.⁹ The response rate of the students across these fields was 61 percent.

In experiences within their departments, women are less likely than men to report that they are taken seriously by faculty and that they are respected by faculty. However, in departments that are overtly improved over time in proportions of degrees awarded to women, there is less gender disparity. Furthermore, in departments that have been increasing the proportion of doctoral degrees awarded to women, that is, improved compared with stably low or high departments, qualifying exams are more likely to be written and are more likely to be reported by women as having “known, objective standards.” This is notable because studies indicate that the more likely that criteria for evaluation are loosely defined and subjective,

DEPARTMENT:

1. Women, compared with men, are less likely to report being taken seriously and respected by faculty.
2. Women in improved departments, especially, report that qualifying exams are written and have “known, objective standards.”
3. Women and men in improved departments are more likely to report a departmental orientation that “teaches students to succeed and moves them along.”

RESEARCH GROUP:

1. Women, compared with men, report they are less comfortable speaking in group meetings.
2. Women report collaborating with fewer male graduate students and male faculty in research and publications during preceding three years.

ADVISER-ADVISEE:

1. Women in high and improved departments, compared with those with low percentages of degrees awarded to women, are more likely to report receiving help from advisers in learning to design research, to write grant proposals, to coauthor publications, and to organize people.

At the same time, across types of departments (low, high, improved), men report receiving *more* help than women in these areas.

2. Women are more likely than men to report that their relationship with an adviser is one of “student-and-faculty” compared with “mentor-mentee” or “colleagues.”

Figure 1: Organizational and Social Contexts of Doctoral Education in Science: Experiences of Women and Men Students

the more likely white men will be perceived to be the superior candidates—and that gender and racial ethnic bias will operate (Fox 1991; Long and Fox 1995).

Students in improved, compared to stably low or high, departments are more likely to report that their departments take a stance of “teaching students to succeed and moving them along” rather than “sifting through them and letting them sink or swim.” Such a pattern may reflect more overt plans and policies in improved departments.

In their experiences in research groups, compared to men, women report that they are less comfortable speaking in group meetings. This is the case within each type of department (high, low, improved). Despite strong preferences for collaboration reported by both men and women students, women report collaborating with fewer men graduate students and men faculty members in research and publications during the three preceding years.

In adviser-advisee arrangements, the women in high and improved, compared with low, departments are more likely to report that they have received help from advisers in crucial areas such as learning to design research, to write grant proposals, to coauthor publications, and to organize people. However, men are more apt to

have received help in these areas across types of departments. Women are also more likely than men to report that they view their relationship with their adviser as one of "student-and-faculty" compared with "mentor-mentee" or "colleagues," which may suggest greater formality and social distance for women students.

Turning to outcomes, women in improved or high, compared with low, departments published more papers and were more likely to report that they will receive their doctoral degree. However, within each of the three types of departments, there is gender disparity in outcomes. Men publish more papers and are more likely to report that they will receive their degrees.

IMPLICATIONS FOR ANALYSIS OF GENDER

These matters of gender, social context, and participation are important because, as I have emphasized, science is a social process—a system of communication, interaction, and exchange (Merton 1996). If women are constrained within the social networks of science—in departments or in the larger communities of science—this restricts their possibilities not simply to participate in a social circle but, more fundamentally, to do research, to publish, to be cited—to show the marks of status and performance in science (Fox 1991).

In certain ways, departments that are improved in the proportion of doctoral degrees awarded to women have social and organizational features that set them apart. Students in these departments are especially likely to report being taken seriously, having written qualifying exams, and perceiving a departmental orientation of "moving students along." The experiences may reflect overt policies and plans in these improved settings. Further and accordingly, site visits to 22 of the 61 departments in which these students were surveyed, and interviews with chairs, graduate directors, and faculty within them, indicate that improved departments have had a past or ongoing history of leadership on issues of women in science (Fox 2000).

At the same time, however, the experiences reported by students show gender disparities that persist across types of departments (low, high, or improved). This points toward a "nonuniformity" *within* departments as they operate for women and men. Different organizational environments are not simply a matter of being located in different types of institutions or settings—large compared with small, or more compared with less improved departments. Rather, within the same type of setting (and indeed, the identical setting), women can have fewer (and different) experiences with faculty, collaborative arrangements, and enabling help from advisers.

In graduate education, a keystone is this. Despite variation between departments in their organizational features and the leadership exercised on some issues of participation and performance of women, departments tend to leave untouched the core of graduate education: the adviser-advisee relationship (Fox 1998, 2000). Individual faculty members are alone in their laboratories with (as they say) their "own students." The departments are decentralized, with faculty and students

working in individual laboratories. Administrations tend to take a “hands-off” approach and, as a result, graduate education is “privatized” (Fox 2000).

Compared to other fields, the decentralization and “privatization” of graduate education is particularly strong in science. This owes, in part, to the importance and high costs of facilities, apparatus, and laboratory staff in science and to the fact that these costs are funded through research grants made to individual faculty. Furthermore, the research programs, external funding, and graduate training in science departments, especially, have been critical to the status and national ranking of universities (Benezet 1977; Long and Fox 1995; Salancik and Pfeffer 1974). Consequently, university administrators have not been motivated to alter the decentralized nature of graduate education by promoting departmental-level, graduate training programs that, compared with graduate education funded through individual faculty research grants, could ensure greater accountability for women (and men) students.¹⁰

Policy and practice on issues of women and science have focused frequently on “increasing the numbers of women in science.” The gender gap in participation in science is a complex issue and a justifiable concern for reasons of social equity and for assurance of a diverse and talented workforce in science. At the same time, however, increasing numbers of women will not necessarily change patterns of gender, status, and hierarchy in science.

Women have long been present in science, although not in valued, highly rewarded, or even visible roles (Rossiter 1982, 1995). Furthermore, for science as for other professions, the relationship between gender, education, and status is complex, so that it is not a simple matter of increasing education and, in turn, increasing professional status. Women’s educational attainments do not translate into scientific career attainments, especially advancement in rank, on a par with men’s (Long, Allison, and McGinnis 1993; Sonnert and Holton 1995a, 1995b).

In addition, increasing numbers of women may not alter the “norms” or “standard practices” of education and work. For example, research by Sonnert and Holton (1995a, 1995b) shows that women in science exercise more care, caution, and attention to detail in their publications and that they are more likely to confirm and integrate research findings before releasing them for publication. Consider the implications of this pattern for gender and status. If, on one hand, women have certain approaches to research, such as a tendency to confirm findings before publishing them, and if, on the other hand, they need to conceal, obscure, or even “overcome” such approaches, then the common norm of proliferating more fragmented pieces of published work may continue to constitute an unchallenged standard for scientific productivity (Fox 1999a, 1999b). This can prevail even though numbers of women in science increase.

There is a broader consideration here, and that lies in the meaning of *difference*. It is not the mere difference in the style of one group or another in science that is critical. In fact, men as a group and women as a group can and do differ widely in their practices. What is especially critical is what does (and does not) constitute a more valued standard and the adherence to, and enforcement of, a given standard.

Sameness or difference always entail a point of reference. The question is, different from what or different from whom? In and out of science, women are usually characterized as “different” from men or a masculine norm. Thus, valued attributes for scientists, such as objectivity, and valued ways of producing science, such as prodigious, albeit fragmented, publication productivity, have been more associated with men and masculinity. A paradox is that in science, these attributes have often been regarded as both “disembodied” and “male” (Fox Keller 1992). In this way, thinking objectively can be considered, simultaneously, “depersonalized” and “thinking like a man.” The power of science and the salience of gendered relations are manifest in the seamless way in which the paradox can prevail without any apparent sense of contradiction among many participating in science (Fox 1999a, 1999b).

WHERE WE CAN INTERVENE—AND HOW

By many indicators, American science has been highly successful—in the extensive numbers of graduate programs established, the scope of laboratories, and the depth and range of the findings and discoveries. Over time, science has advanced through challenges to established intellectual paradigms, with struggle along the way. Likewise, science can be advanced by critical attention and challenge to established organizational practices and arrangements, with consequences for the significant participation and performance of women and other under-represented groups.

Doing this entails paying attention to the organization of the workplace, its methods of evaluation, the distribution of power, and the status of women and racial/ethnic groups. To illustrate, some of the organizational practices and policies that support gender equity include the following:

1. When departments fund students through federal grants (and most do), they need to put into place written guidelines on the expected benchmarks, by year in graduate school, on matters such as courses of study, exams, and other evaluations.
2. Likewise, guidelines and benchmarks need to be specified for faculty salary and promotion in rank. Flexibility and informality are “ok” organizational words (Huber 1973, 3), but they present conditions that advantage those who “look like” those currently in power and tend to support bias rather than equity in the workplace (Fox 1991, 191; Long and Fox 1995, 63).
3. Practices such as placement of students and junior faculty members in existing research projects affect research opportunities in fields that are highly collaborative (Feldt 1985, 1986) and need attention.
4. Start-up funds for laboratories, teaching assignments, and patterns of release time should be subject to equitable standards, rather than being administrative favors bestowed or withheld.
5. The proliferation of fragmented publication can be discouraged by lowering the incentive and rewards for it, as federal agencies have done by limiting the listing of principal investigators’ publications in grant proposals to their five most relevant articles.

Clearly, women in science are a highly selective and qualified group, with ability and educational attainments as high (or higher) than their male counterparts. The solutions for women's advancement are not a matter of correcting personal deficits. Rather, because science is organizational work, subject to organizational signals, priorities, and rewards, it is important to identify and attend to the enabling or disabling features of the settings in which scientists study and work.

What we need to bear in mind is this: Just as organizations are structured, so they can be restructured. The structure is not written in stone, it was not inscribed on a sacred mount, and it is not an inalterable plan. It is social and it is malleable.

Fundamentally, organizational transformation takes organizational will. Those with authority to influence others and accomplish goals can do so by directing the flow of material and social rewards (or the flow of sanctions). In academic science, this means examining the existing ways of organizing departments, evaluating participants, and distributing resources, not just for the attainment of more science degrees but for gender equity in research, collegial opportunities, and career outcomes. That is an organizational, as well as individual, enterprise. And it is our challenge ahead.

NOTES

1. This framework of gender, hierarchy, and science draws from Fox (1999a) and is discussed in more detail there.

2. The gender difference owes principally to the higher concentration of men in engineering fields, which are in turn more likely than the other science fields to be practiced in nonacademic, industrial settings.

3. The latest year for which these data are available by fields is 1995.

4. This grouping includes earth, atmospheric, and ocean sciences; mathematical/computer sciences; and physics and chemistry (Commission on Professionals in Science and Technology 1997, 47, n. 2).

5. This is true throughout women's history. Accounts of the Renaissance and Reformation periods, for example, cast doubt on the notion that increased access to literacy resulted in greater gender equality for women (Prentice 1981, 46-47).

6. In chemistry, for example, at doctoral-granting institutions between 1985 and 1990, women went from 11 percent to 18 percent of assistant professors; from 9 percent to 13 percent of associate professors; but only from 3 percent to 4 percent of full professors (Roscher 1990, 72-73). These proportions are to be considered against the growth in women's share of doctoral degrees awarded in chemistry: 7.7 percent in 1970, 11 percent in 1975, 17 percent in 1980, 20 percent in 1985, and 25 percent in 1990 (National Center for Education Statistics 1993, Table 240; Roscher 1990, Table 11) and the maturation of the cohorts during the period.

Engineering is the most recent field to show increasing numbers of doctoral degrees awarded to women. Women's share of doctoral degrees in engineering fields increased from 1.4 percent in the 1970s to 5.9 percent in the 1980s and 9.8 percent in the 1990s. We will need to look at engineering again in a few years and see where women stand in academic rank. It may be different than for the other fields of science. This is because engineering has a strong industrial sector for doctoral-level scientists, with resulting competition for engineers in academia, including competition for women engineers, perceived to be important for the recruitment and retention of high-quality women engineering students (see Fox 2001; Fox and Stephan 2001).

7. An exercise in parsimony, Figure 1 summarizes data from 20 separate figures. The purpose here is to convey trends and patterns, rather than particular values and levels of the indicators.

8. Microbiology students were also surveyed but not included in this summary. This is because in the life sciences, field of degree does not necessarily correspond to the department in which it was obtained, making it impossible to sample in categories of departments that were relatively low, high, or improved in degrees awarded to women.

9. The first five years are 1974-78, except for computer science (1978-82) and electrical engineering (1977-81); the last five years are 1986-90. Sampling details may be found in Fox (2000).

10. For discussion and recommendations on federal investment in training grants and on individual graduate fellowships, compared with faculty research grants used for support of graduate education in science, see the report of the National Research Council (1998).

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