The Paradox of Critical Mass for Women in Science

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the NIH budget will not keep up with inflation. Of the grant applications selected as scientifically promising, fewer than one in four were funded last year (19). But, if basic research is so cost-effective, one may ask, why isn’t it fully supported by the insurance or pharmaceutical or biotechnology industries? Because scientific inquiry can take years and lead in unexpected directions, the potential financial returns on any single scientific investigation may not justify the investment in the short run. Like the construction of interstate highways, biomedical innovation pays for itself times over in the aggregate, but it is too big an aggregate for any private investor. The provision of this kind of public good is an appropriate role of the government.

Although biomedical innovation was ignored in the Clinton health plan in Congress, there has been strong bipartisan support for increased investment in biomedical research as part of health care reform. Many members of Congress are recognizing the importance of training scientists and physicians, maintaining research hospitals and facilities, and continuing the flow of new discoveries. Despite the current dwindling of discretionary spending, many senators and representatives have proposed a Medical Trust Fund which would provide 1% of health care insurance premiums for biomedical research. The fund is based on the principle that just as industry invests in research with a profit motive, some part of health care reform should invest in biomedical research with a goal of cost saving and quality improvement.

After the inevitable political compromises to enact health care reform, it is critical that the resulting policy includes appropriate incentives for cost-reducing innovation and adequate public funding for NIH to support basic biomedical research. Federal support for biomedical research, which has focused on the benefits to health, should incorporate a realistic accounting of the contribution of innovative research to cost control as well. Past biomedical innovation has made major contributions in advancing medicine and significant contributions to cost reductions in spite of skewed incentives. With corrected incentives, the promise of future biomedical innovation to reduce costs is enormous. Only innovation will enable the dramatic and sustained cost reductions required for successful health care reform.

REFERENCES

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Henry Etzkowitz,* Carol Kemelgor, Michael Neuschatz, Brian Uzzi, Joseph Alonzo

A minority group (especially one that has traditionally been discriminated against) is easily marginalized when only a small presence in a larger population; its continued presence and survival is in constant jeopardy, requiring outside intervention and assistance to prevent extinction. As the group’s presence and level of participation grows, at a particular point the perspective of members of the minority group and the character of relations between minority and majority changes qualitatively. In theory, the minority is increasingly able to organize itself and insure its survival from within and effects a transition to an accepted presence, without external assistance, in a self-sustaining process (1). The discrete point at which the presence of a sufficient number brings about qualitative improvement in conditions and accelerates the dynamics of change is known as “critical mass” and has been defined as a strong minority of at least 15% (2). Change, without struggle, however, is less likely than conflict with determined resistance. Under certain conditions, an organizational transformation culminates in minority group members achieving and retaining positions of real power and authority that were previously beyond their grasp (3).

To evaluate the dynamics and effects of these transitions for the problem of increasing participation of women in science, we studied 30 academic science departments in five disciplines (biology, chemistry, physics, computer science, and electrical engineering), comparing those departments that had been relatively successful in graduating female Ph.D.’s to those that had not (4). We also compared departments where a critical mass of women existed to departments where it was lacking.

A key finding was that as the number of women faculty members in a department increased, they divided into distinct subgroups that could be at odds with each other. Senior female scientists typically shared the values and work styles of older men; their narrow focus failed to meet the needs of most younger women. In contrast, some younger women (and a few men) struggled to create an alternative scientific role, balancing work and nonwork issues.

The scientific role thus bifurcates along generational and gender fault lines. These developments have significant unintended consequences for the socialization of female scientists, for example, the availability of relevant role models. As long as the relatively few women in academic science were willing to accept the stricture of a workplace organized on the assumption of a social and emotional support structure provided to the male scientist by an unpaid full-time housewife or done without, issues of women in science were not attended to. A modest increase in the numbers of women in science, without a change in the structure of the scientific workplace, creates a paradox of critical mass.

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Attaining Critical Mass

Alice Rossi’s question of almost 30 years ago:
“Why so few women in science?” must be
revised to reflect changing patterns of partici-
This proportion of women among doctoral
scientists and engineers doubled be-
tween 1975 and 1991. But while all fields
showed gains, the starting points and rates
of change have varied widely from discipline
to discipline (6).

Women-friendly subfields have emerged in
the life sciences and in biologically ori-
ented subfields in chemistry, biochemistry;
computer science, artificial intelligence
where cognitive processes and psychologi-
cal links are prevalent; and in the bioelec-
trical subfield of electrical engineering.
These fields tend to be ones that women
select or are subtly or not so subtly directed
into. In a snowball effect, as numbers in-
creased, more women were attracted.

We found that modest increases in the
number of women did bring about some
change in departments. In this respect,
critical mass does work smoothly: There is
more support and safety in numbers. A
female student observed that, “One good
thing is that there were female faculty
members. It definitely changed my atti-
gitude of how male students react to wom-
en. They must take them seriously and
this is positive.” When senior females
were present, overt male behavior toward
women improved (for example, invidious
public sexual joking and stereotyping de-
clined); this change is a threshold effect
of critical mass.

Involvement of respected senior faculty
members also was the key to some instances
of actual departmental reform. A “revolu-
tion from above” opened up a tenure slot for
a woman when members of a male leadership
group in one department became aware of,
and decided to eliminate, implicitly discrimi-
natory practices. A cultural change was initi-
ated as well, making the department amena-
able to the presence of women. Sympathetic
men as well as women served as change
agents.

For these reasons in departments with no
women faculty, female graduate students
often had high expectations about the pres-
ence of a female faculty member. A female
graduate student said:

I wish we had a woman because the men don’t
understand the issues that the women are con-
cerned about. I thought about going to the chair
and telling him to put all the new graduate stu-
dents in the same area of the building because it’s
really helped us get through the first year. But he
may say, “why?” Maybe that’s not important to
the men. But if there was a woman who was
higher up then I could say this is really cool to
have some companions, some support system
here, and she might say, “Yeah, that’s really a
tonight.”

Another female graduate student ex-
pressed the need to learn how to comport
herself as a woman in professional situa-
tions:

If I had the choice of a female [adviser], I
would choose one. She would be a role model in
regard to how to dress, how to act at conferences, what
to do when someone is curt to you. I am more
than willing to admit that there are differences in
the genders. I would like to have someone who
can show that I can do it. I am looking for
sensitivity about the issues that I perceive that I
deal with. Men and women have different issues.

However, particularly in the absence of
a critical mass, expectations about the abil-
ity of individual female faculty, especially
those who are untested, to bring about
change in departmental conditions are
unlikely to be realized. A junior female
faculty member recounted the perils:

My gut level feeling was that the attrition for
females was higher; I went off the rails in one of the
programs, and looked over the past 10 years. You
could see by the number of women admitted, and
then in a 6-year-frame shift of how long it takes to
graduate, that there was a big difference between
male and female attrition. With our male col-
leagues you need hard data, or else they won’t
accept it. So I took a particular year and followed
the students, and within the first 2 years 30% of
the females had left. The males were 17%. I mentioned
this to one of my male colleagues, who told me I had
lost my mind. He just said it wasn’t possible for this
factor to be true. They don’t realize. They have no
concept. Once confronted with actual numbers and
people, they say, “well, we ought to know about this.
Nobody’s ever told us.” First there’s general disbelief.
Then you show them the data and they look at it and
they’re honestly shocked. They personally don’t rec-
ognize it in their everyday lives. One [colleague] told
me I was lying. They said “why don’t you give a
presentation to the faculty at a faculty meeting and
discuss this fact. Show us the hard data.” I’m not sure
that I want to put myself on the hot seat like that. Get
up in front of the whole faculty! As strongly as I feel
about this, I don’t want to subject myself to what
might possibly happen by standing up in front of
a group of those people and telling them what is going
on in the department.

As an isolated individual, there was little she
could do given expectations of an invidious
response.

Even worse, in some cases, stigmatiza-
tion of women accompanied the breakdown
of gender uniformity. Seemingly innocuous
measures like calling together an informal
group of women were sometimes perceived
negatively and forestalled. Untenured wom-
en, concerned that participating in activi-
ties for women would set them apart, were
sometimes unwilling to participate.

The Paradox of Critical Mass

We found that attainment of critical mass
only partly resolved the dilemma of women
in academic departments. The fallacy of
critical mass as a unilateral change strategy
is that female faculty pursue strikingly dif-
ferent strategies. Despite some progress, or-
ganizational structures within departments,
and the divisions they engendered, contin-
ued to isolate women. Furthermore, the dis-
peral of women students into male-domi-
nated research groups sustained isolation
even when there was a critical mass in a
department. Nor did an improvement in
the total number of women in a department
necessarily overcome an underlying situa-
tion of subfield fragmentation that further
increased the isolation of women.

Isolation is widely recognized as a prob-
lem for women in academic science, carry-
ing with it a variety of negative conse-
quences including stigma, depletion of self-
confidence, and exclusion from access to
informal sources of professional informa-
tion. Informal networks are indispensable
to professional development, career advance-
ment, and the scientific process. Contiguity
of helpful colleagues improves the condi-
tions for scientific achievement; lack of
sympathetic interaction depresses it. Isolat-
ed individuals not only lack social psycho-
logical support, but also the social capital
underlying success (7). As outsiders, some
female scientists developed strategies to
make up for these deficits.

The differentiation of female faculty
produces isolation even when the numbers
reach critical mass. Even when there are
several female faculty members present, fe-
male student expectations for change may
be thwarted. In this depart-
ment, “you are either a superstar or you’re
marginal. I came here to find a critical mass
of women faculty who would be cohesive.
But they’re not. They are isolated from each
other.”

Even when isolation should be reduced by
the presence of several women faculty
members in a department, their dissen-
sus was apparent. Indeed, female graduate
students in our sample expressed surprise and
discouragement at encountering this unex-
pected phenomenon. This is especially the
case for entering female graduate students
with little or no awareness of the appropri-
ation of the male model of doing science by
women faculty or of the pressures on them.
Such false assumptions on the part of fe-
male graduate students often lead to disap-
pointment, frustration, and even anger or
despair.

“Male” and “Female” Models

One reason for continued isolation and the
paradox of critical mass was that female
scientists split into subgroups following one
of two paths, “the traditional male” and
“the relational female” models. Thus, as it
was achieved, some of the expected effect of
critical mass dissipated. A modest increase
in the number of women has brought about
a breakdown of a unitary male model, but the growing number of women students often lack viable role models in the interim, as normative change takes hold. Some female scientists singularly focused on science, and their identity was narrowly based on research and career achievement. Marriage and children were secondary for these women; most waited until after achieving tenure to marry and start a family, if they chose to do so at all. A senior female scientist described her cohort:

The ones who did [science] were really tough cookies. Now it’s easier to get in. At one time it wasn’t even acceptable to start. So if you started back then you were tough to begin with. I have quizzing women coming through who are very smart asking can they compete with men, and can they compete on a very competitive, fierce playing field. Of course they can. They just are not taught to be competitive. They don’t expect to win. The reason why I am successful is because I never felt this way.

Their experience in overcoming discrimination led these scientists to expect that women had to be better than men in order to succeed; they trained their female students accordingly. A female graduate student described her adviser: “The generation of women scientists that [my adviser] belongs to, some of them feel they have to go that extra professional push to be taken seriously or to gain the same respect from their peers that men do. [My adviser] said you have to be careful how you present yourself. You have to be more rigorous.” They felt they had to be tougher on women students than men, to prepare them to meet the higher standards they would be held to as women.

Female scientists following the male model believed they were helping their female advisees by toughening them up to survive in a harsh environment. A female graduate student reported that:

I happened to pick a woman adviser . . . which turned out to be somewhat of a mistake. I was under the impression that having a woman adviser would make life a little bit easier. . . . It turned out to be worse. . . . Their motto is sink or swim. . . . My adviser’s approach was to put it too far out of my grasp.

This response from a woman was experienced as debilitating and depressing and was taken more negatively than if it had come from a man.

Fear of stigmatization led some women who have made it to deny the existence of gender-related obstacles. Calling attention to difficulties overcome could lead to countercharges of special privileges received, devaluing their achievements. Frustrated by the emergence of women’s issues, they regarded such concerns as indicative of lack of commitment to science. They believed women’s groups and programs to improve the condition of women harmed female scientists by making them appear “different,” and by implication less competent. Most women following the male model are from a courageous older generation; it is premature to conclude that academic science has opened up sufficiently to make their stringent approach, which was highly adaptive in the past, irrelevant today.

“Only a relatively few women are willing to follow the male model and even some men would like to modify it. Some males, both students and faculty, are struggling with some of the same issues of balancing career and family as women. Some junior male faculty were more sympathetic mentors than some senior female faculty. It is not only the number of women faculty members that aids female students; a conundrum of information about negotiating the social structure of science, both its hidden and visible rules, is crucial. This information can come from women or men.

Thus, some women scientists whom we interviewed have formulated an alternative scientific role and work style based on creating a collegial and supportive environment in their research laboratories (8). Meyerowitz (9) argued science as only one part of their identity, they survived to balance the demands of career and family. Integrating science and personal life was the paramount issue for women students. A female chemist said, “The biggest problem women students have is how to do with the whole culture: How do you do [science] and have a normal life? It’s a constant problem. They ask me when they should have children, can I take a part-time postdoc and then get back in? I don’t know (the answers). I can’t help them.”

These female scientists struggled to find the best time to schedule their pregnancies, given a rigid academic career structure demanding early achievement (9). They viewed themselves and their husbands as the mutual primary caregivers of their children and were unwilling to turn this responsibility over to others. Nevertheless, they were interested in high-quality child care as a secondary support system and often felt frustrated at the low priority this need was given at most universities. A female faculty member said:

I have seen female graduate students come to this department who are exceptional, who did not leave because of academics whatsoever. Outnumbered many of the men by orders of magnitude, and they’re gone. And I consider that such a waste. I look at these people as being excellent people who could go on and be in academia, and they leave with a master’s because they say they don’t want to live like this. They see what people have to do to succeed in academia. They look at a junior faculty member and what they have to do, and they extrapolate what they would have to do for themselves. The women want to have another life; they want a family, [to] be able to socialize on the weekend. It doesn’t have to be like that, but that’s what they see; working on the weekends and every night.

Women scientists’ unmet needs have posed several other problems as well. The limited acceptance of a female relational model and a mentor’s career setback were discussed by a female graduate student:

I was so upset when I found out that she didn’t get tenure at this time because she’s been such an asset to me and so many other women that I know and mentor. As someone I could look at and say I could be there someday. Someone who actually proves the reality that there can be a professor [there] who is normal, that you can relate to. She is a role model. I’m not sure what I want to do right now, but I wanted to have the opportunity of going into academia open. She seemed like an open end in that direction. When the door was closed on her, I felt the door was closed on me too.

Without such role models, women are less willing to attempt careers in academic science. Invidious definitions of female affiliation highlight the structural nature of the problem and the need to address isolation at the highest levels of academic and science policy (10).

Policy Implications

Critical mass was expected to be achieved through affirmative action, to clear up blockages in the pipeline on the premise that a sufficient number of persons from a previously excluded social category will foster inclusion of others from that background. From the 1970s, efforts to increase the number of women in academic science departments have largely resided in affirmative action programs, requiring full consideration of female and minority candidates. However, in the 1980s lack of vigorous enforcement reduced the spirit of the law into a bureaucratic requirement that became a routine part of the paperwork of the academic hiring process, often with little or no effect on recruitment and no impact upon retention (11). Nor did this strategy, focused on getting entrants into the system, address the hidden inequities of academic departments.

The paradox of critical mass and the interest of many female scientists in creating an alternative relational mode of doing science suggests that a significant increase in the number of women in academic science is unlikely to occur simply by increasing the numbers of women who embark on a scientific career. Encouraging more women to enter the pipeline is fruitless if so few women become professional scientists. At each transition point the number of women decreases at a significantly higher rate than for men: For women the pipeline is an exceedingly leaky vessel. In the face of exclusionary practices, both explicit and implicit, built into the research university system, many women Ph.D.’s, seeing the handwriting on the wall and seeking to balance work and personal life, sought employment in industry and teaching colleges. As our observations emphasize, the pipeline, a sup-

53

SCIENCE • VOL. 266 • 7 OCTOBER 1994
ply-side approach needs to be supplemented by a focus on changing the institutional structures where science takes place.

A key factor in overcoming the problems posed by the paradox must be university-wide policies and programs regarding child care, parental leave, recruitment and retention, and the curving of the tenure clock (12). At the departmental level, junior faculty who assume mentoring and role modeling functions should be credited in tenure reviews. Tokenism must be eschewed: Many departments aggressively court a few female stars while most women languish in continued discrimination.

Some reforms must come from internal initiatives, overcoming divisions arising from the emergence of subgroups following male and female models. Female scientists in academia and industry have undertaken innovative efforts to reduce isolation and provide information and support to graduate students. Electronic mail lists, such as SYSTERS for women in computer science and an electronic mentoring project, drew geographically isolated individuals together into an informal network (13). Some departmental secretaries took upon themselves, or were assigned, the task of organizing support groups. University counseling staff also provided a resource for female students. Another change strategy, organizing retreats and support groups, was sponsored by some departments and the National Science Foundation (NSF) Engineering or Science Centers.

Nevertheless, the ability of departments to defend traditional academic practices as gender neutral should not be underestimated, nor should willingness to reform themselves be overestimated. Unable to reform themselves, outside pressures provide the necessary incentive for most departments. A representative of WISE (Women in Science and Engineering at Columbia University) recently suggested that the NSF cut off grants to universities without a minimum number of female faculty in science and engineering departments. Indeed, NSF has mandated that absence of women at conferences that it funds will be taken as prima facie evidence of discrimination. Single-sex graduate departments have also been proposed to address the persistent exclusion of females from male inner circles (14).

Legal action is a final resort. Until quite recently, courts were generally unwilling to review academic decisions on substantive grounds; only matters of procedure were typically subject to judicial review. Gender discrimination has now been accepted as a valid basis for law suits challenging academic decisions, following widespread acceptance of its legitimacy in other workplaces. Jenny Harrison, a University of California, Berkeley, mathematician, was recently granted tenure after such a suit. The recognition she received for a series of significant results made the initial negative decision a matter of some embarrassment to the mathematical community. Academic exceptionalism, whether in the courts or Congress, is disappearing as universities are held to ethical, legal, and financial standards common to all public institutions.

Participation of all groups in society is a basis for the public support of science. The legitimation of science, the moral injunction to achieve equity, and the strategic national interest in utilizing talent to its fullest extent are reasons for change. Neal Lane, the director of NSF, has called upon the research community to act in its own self-interest and make a conscious effort “to integrate itself into the larger community” by more closely reflecting the demographic composition of the population (15). Equal representation of women and men in scientific professions would counter the elitist image of science and hopefully earn increased support for allocation of public resources to science.

REFERENCES AND NOTES


4. We conducted 155 interviews with female graduate students and faculty members in 30 departments at Carnegie I and II level universities. We also interviewed male faculty members and graduate students in three departments. Six departments were selected in each discipline, namely, the two departments with the consistently highest proportion of Ph.D.’s awarded to women over the entire period, the two departments with the consistently lowest proportion awarded to women, and the two departments exhibiting the greatest improvement in that proportion between the mid-1970s and 1990.


6. Although the proportion of Ph.D.’s awarded to women in the sciences and engineering more than doubled from the average for the 1960s to the average for the early 1990s, women’s membership in the faculty of academic science and engineering departments is checkered. Many biology departments have a significant female presence in a variety of subdisciplines, whereas many computer science departments still do not have a single female faculty member [D. Gries and D. Marsh, Computer 23 (no 10), 65 (1990)]. The number of women faculty in academic physics and mathematics departments was too small for meaningful analysis, and in the 1993 data (T. S. Botet, Fair Science: Women in the Scientific Community (Free Press, New York, 1978)), and that situation is still largely true in those fields. While the proportion of women rose from 14.4 to 23.8% in biological science departments, the gains in chemistry were from 7.9 to 12.3%, and in computer and information science from 7.0 to 9.6%. Physics-astronomy and engineering, while showing some of the fastest increases, remained far back at 4.6% and 2.7%, respectively, in 1989 [Committee for Professionals in Science and Technology (Washington, DC, 1994), pp. 22 and 46].


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