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Transforming Science and Technology: Has the Elephant Yet Flicked Its Trunk?

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Over the past two decades, the tremendous growth and expansion of feminist scholarship in the humanities and the social sciences has prompted Catharine Stimpson to say that "[w]omen's studies has produced a body of thought so big, complex and vital that people who ignore it should be sued for intellectual and academic malpractice."[1] This growth of women's studies, from a few courses in the late 1960s to over five hundred programs today, has occurred almost exclusively in the humanities and the social sciences.[2] But what of the sciences and engineering? What impact has a feminist analysis had on them?

Following the emergence of the second wave of the women's movement, and accompanied by the women's health movement, feminist analyses of science and technology began appearing in the mid- to late-1970s and steadily appeared until the mid-1980s.[3] In the past five years, the publication of books on the history of women in science and invention, women in science and technology, and science, technology, and gender has flourished. These critiques of science and technology have provided crucial insight into the social construction of science and

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[1] Catharine R. Stimpson, "Setting Agendas, Defining Challenges," *The Women's Review of Books* 6 (February 1989): 14.

[2] Stimpson, "Women's Studies Programs Continue to Expand," *NWSAction* 2 (Spring 1989): 4.

[3] A few of the early volumes include Anne Sayre, *Rosalind Franklin and DNA* (New York: Norton, 1975); Evelyn Reed, *Sexism and Science* (New York: Pathfinder, 1978); Ethel Tobach and Betty Rosoff, eds., *Genes and Gender: First in a Series on Hereditarianism and Women* (New York: Gordian Press, 1978); Martha Moore Trescott, ed., *Dynamos and Virgins Revisited: Women and Technological Change in History* (Metuchen, N.J.: Scarecrow Press, 1979); Ruth Hubbard, Mary Sue Henifin, and Barbara Fried, eds., *Women Look at Biology Looking at Women* (Cambridge, Mass.: Schenkman, 1979); Hubbard and Marian Lowe, eds., *Genes and Gender II: Pitfalls in Research on Sex and Gender* (New York: Gordian Press, 1979); Ruth Schwartz Cowan, *More Work for Mother: The Ironies of Household Technology from the Open Hearth to the Microwave* (New York: Basic Books, 1983); and Joan Rothschild, ed., *Machina ex Dea: Feminist Perspectives on Technology* (New York: Pergamon Press, 1983).

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technology, and they have revealed many biases and false assumptions. Critiques of natural science, for example, have informed feminists in many disciplines about the sexism of biological theories of gender and the nature of male-dominated science itself. This, unfortunately, has had a limited influence on the sciences and technological fields.

Ruth Bleier, neuroanatomist and feminist activist, used her knowledge as a scientist to critique biological theories of gender, especially those theories involving hormones and the brain in relationship to sex differences. To describe the influence of feminist criticism on science so far, she characterized male-dominated science as an elephant. "[T]he elephant has not even flicked its trunk or noticeably glanced in our direction, let alone rolled over and given up."[4] Bleier observed that the vast majority of those working in science, engineering, and technological fields are not aware of feminist critiques of their work; nor would most of them be vaguely interested. In fact, feminists have had pitifully little influence on the day-to-day business of science and technology. Nonetheless, women's studies should formulate a plan to transform the sciences and technology.

The purpose of this paper is to outline strategies for transformation that can be implemented by women's studies programs and departments. Since I am a geneticist, this paper is oriented toward the sciences. Although science and technology are closely related, it is important for readers to understand that science and technology are distinct fields. Science, specifically, is the study of the natural world using observation and experimentation, while technology is the transference of scientific knowledge into the creation of tools for human use.

Before feminists can begin to transform science and technology, they need an understanding of its social construction. Thomas Kuhn's book *The Structure of Scientific Revolutions* has greatly influenced the sociology of knowledge and the history and philosophy of science by demonstrating that scientific inquiry is a product of a given frame of reference. Kuhn discussed the social and scientific paradigms in which science is conducted. Out of a social paradigm composed of "the entire constellation of beliefs, values, techniques, and so on shared by the members of a given community," a field of scientific study narrows to create its own scientific paradigm, which imposes another set of limitations on questions that can be asked and researched.[5] Students of science are taught scientific

[4] Ruth Bleier, *Feminist Approaches to Science* (New York: Pergamon Press, 1986), 1. Bleier's work on sex differences and the brain can be found in her book *Science and Gender: A Critique of Biology and Its Theories on Women* (New York: Pergamon Press, 1984).

[5] Thomas Kuhn, *The Structure of Scientific Revolutions*, 2nd ed. (Chicago: University of Chicago Press, 1970), 175.

facts and theories within the structures of these paradigms, without anyone acknowledging the existence of these strictures. Kuhn explained the influence this has on scientific inquiry:

> The study of paradigms . . . is what mainly prepares the student for membership in the particular scientific community with which he [sic] will later practice. Because he there joins men who learned the bases of their field from the same concrete models, his subsequent practice will seldom evoke overt disagreement over fundamentals. Men whose research is based on shared paradigms are committed to the same rules and standards for scientific practice.[6]

Kuhn's book focused on how shifts in scientific thinking and knowledge take place, but others who have built upon his work place the scientific endeavor into a social context.

Most practitioners of science who deny social influences on scientific research and theories use science's most sacred defense—objectivity. Recognizing evidence of bias in science is crucial, if the facade of objectivity is to be dismantled. The most blatant social prejudice to pass as science has been the racist biological theories of eugenics, a pseudoscience purporting to judge the superiority/inferiority of an individual from her or his racial and ethnic origin.[7] In the past two decades, an understanding of the social influences in the development of gender have exposed an androcentric bias and sexism in biological theories as well. Feminist analyses of science have been formed by merging the study of the social construction of science with the study of the social construction of gender. When the terms used to characterize science are compared with the traits considered to be masculine, one finds that many of the terms are the same. Characteristics such as objectivity, rationality, and logic are highly valued. Are these characteristics esteemed because they are descriptors of the highly regarded science and technology or because they are seen as masculine traits? The answer is that they are both; masculinity and the practice of science and technology are so intertwined that science can be seen as the institutionalization of masculine traits and values.

In her book *Reflections on Gender and Science,* Evelyn Fox Keller, a mathematical biophysicist turned philosopher, asks "[h]ow much of the nature of science is bound up with the idea of masculinity . . .?" In exploring this question she describes what she calls the science-gender system. This system is created by excluding women from decision-making

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[6] Kuhn, *Structure of Scientific Revolutions,* 11.

[7] Although other publications have preceded these, the following two are detailed accounts of scientific racism: Allan Chase, *The Legacy of Malthus: The Social Costs of the New Scientific Racism* (New York: Alfred A. Knopf, 1975); and Daniel J. Kevles, *In the Name of Eugenics: Genetics and the Uses of Human Heredity* (New York: Alfred A. Knopf, 1985).

positions in science and engineering and results in science and technology being produced by a "subset of the human race . . . white, middle-class men." Further examination of the science-gender system prompts Keller to "ask how ideologies of gender and science inform each other in their mutual construction, how that construction functions in our social arrangements, and how it affects men and women, science and nature."[8]

Other feminists in science also have been critical of the androcentric nature of science. In *The Science Question in Feminism,* Sandra Harding writes,

> The radical feminist position holds that the epistemologies, metaphysics, ethics and politics of the dominant forms of science are androcentric and mutually supportive; that despite the deeply ingrained Western cultural belief in science's intrinsic progressiveness, science today serves primarily regressive social tendencies; and that the social structure of science, many of its applications and technologies, its modes of defining research problems and designing experiments, its ways of constructing and conferring meanings are not only sexist but also racist, classist, and culturally coercive.[9]

At first it can be very difficult to see science's negative attributes, since they are camouflaged by our respect for the abstract concepts of knowledge and truth. Elizabeth Minnich explains how the elitism of science is so constructed by society's privileged, dominant group that some of science's fundamental premises go unrecognized and unquestioned.

> "Knowledge is power" is perhaps a truer statement than we often realize; like many cliches, this one may have persisted because it expresses something common sense stubbornly grasps despite mystifications. In any case, like power, knowledge depends on the agreement of a significant group of people and establishes itself more firmly as their organization grows. And when that organization is of professionals whose knowledge is itself high in the hierarchy, power takes on the further mantle of authority. In such organizations, it is not at all surprising that the articulated hierarchy of "kinds" of people is also replicated. All you need do here is picture a room full of elementary school teachers, and another full of professors of physics. Which group is composed of representatives of the top of the gender/race hierarchy? And yet we are supposed to believe that science is of all fields the most disinterested, neutral, nonpolitical. Of course it seems that way; it so fits the dominant system that it isn't even seen as systemic.[10]

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[8] Evelyn Fox Keller, *Reflections on Gender and Science* (New Haven, Conn.: Yale University Press, 1985), 3–8.

[9] Sandra Harding, *The Science Question in Feminism* (Ithaca, N.Y.: Cornell University Press, 1986), 9.

[10] Elizabeth K. Minnich, *Transforming Knowledge* (Philadelphia: Temple University Press, 1990), 161.

Much of the writing by feminists has exposed and confronted the androcentricity and positivism of science and technology. In some feminist eyes, science came to be seen as so permeated with androcentric values and practices and so invulnerable to change that the only solution was a rejection of science and technology. Once our minds had been colonized by the dominant group's frame of reference and way of thinking, imagining alternatives became a challenge. Several years ago Sue Rosser wondered "is reconceptualization possible?" At that time Rosser thought "[i]t would be very surprising if we could reconceptualize a feminist science from within our current sexist society," although she maintained that "[i]t is important not to be discouraged because we cannot yet see the exact form that the reconceptualization will take."[11] Since then, much theoretical work has been done on the nature of feminist science. Questions have been asked such as: "Can science be feminist?" "What will a feminist science be like?" "How will science change if it is done by feminists?"

Feminist philosopher Harding does not think that techniques of data gathering would change if done by feminist scientists, but certainly the questions that would be asked and the kind of research conducted would be different under a feminist consciousness.[12] Helen Longino, who has written on science from a feminist perspective, rejects the concept of a feminist science, but does not see this rejection as disengaging science from feminism. She, like Harding, would "focus on science as a practice rather than content, as process rather than product; hence, not on feminist science, but on doing science as a feminist."[13] We should not be surprised to learn that women have been doing science in a "gynocentric" way for centuries. Ruth Ginzberg shows us that midwifery is the gynocentric science that was practiced before the androcentric science of obstetrics replaced it.[14] The strength of the feminist influence on science and technology lies in what feminist analysis is able to do best, which is analyze power, authority, and privilege by asking the questions: Who has it? How did they get it? Who benefits? Who suffers?

Male-dominated systems of science and technology are vital to a male-dominated society. They justify the society's very existence. Science "uncovers" evidence of biological male superiority and female inferiority, and then male-controlled technology develops techniques that maintain the oppression of women. Every descriptive term that has been used to

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[11] Sue Rosser, *Teaching Science and Health from a Feminist Perspective: A Practical Guide* (New York: Pergamon Press, 1986), 4.

[12] Harding, "Is There a Feminist Method?" in *Feminism and Science,* ed. Nancy Tuana (Bloomington: Indiana University Press, 1989), 17–32.

[13] Helen E. Longino, "Can There Be a Feminist Science?" in *Feminism and Science,* 45–57.

[14] Ruth Ginzberg, "Uncovering Gynocentric Science," in *Feminism and Science,* 69–84.

characterize patriarchy applies to science as well. Therefore, feminist exposure and confrontation of androcentric science is deeply threatening to the social norms of the dominant group. When feminists attempt to transform androcentric science and technology, they are taking on the heart of patriarchy. If feminists get the elephant of male-dominated science to roll over and give up, patriarchy itself will have ceased to exist.

The challenge is immense, but revolutions in science and society have occurred before as Minnich points out.

> Consider the example of geocentrism. Copernicus's move to put the sun at the center of the cosmos was greeted as what it indeed was, a challenge to many of the most deeply held beliefs of his culture, and more—a challenge to a remarkable range of systems of explanation, of knowledge, even of mores and morals. Darwin's theory of evolution had, and for some still has, the same devastating effects. It dethrones Man, suggesting that he is *not* the center, is not a unique creation that is discontinuous with and superior in kind to all else. Shifting from an invidiously hierarchical view of humankind entailed then, and entails now, a concomitant shift in all areas of knowledge, of ethics or politics. . . . What we (feminists) are doing, is comparable to Copernicus shattering our geo-centricity, Darwin shattering our species-centricity. We are shattering androcentricity, and the change is as fundamental, as dangerous, as exciting.[15]

To bring about such a revolution we need more women in science and engineering. Women currently make up only 11 percent of the nation's science and engineering workforce, even though they make up 45 percent of the total workforce in the United States.[16] Among employed women scientists and engineers, roughly 5 percent are black; 5 percent are Asian; 3 percent are Hispanic; and less than 1 percent are native American.[17] Since not all of these women in science and engineering are feminists, the few women scientists who are feminists are working, on a day-to-day basis, in isolation from others of similar political ideology. Before transformation can occur, most feminists agree that we need a "critical mass" of women and more specifically, feminists in the science and engineering disciplines.[18]

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[15] Minnich, *Transforming Knowledge,* 34.

[16] Task Force on Women, Minorities, and the Handicapped in Science and Technology, *Changing America: The New Face of Science and Engineering, Interim Report* (Washington D.C., 1988), 36.

[17] Scientific and Technical Personnel Studies Group, "Women and Minorities in Science and Engineering, Report NSF 90–301," in *National Science Foundation News,* NSF 90–2, 29 January 1990, 2.

[18] Rosser, *Teaching Science,* 7.

The changing demographics in the U.S. are working in our favor and will ensure that we will have more women in science. Over the past two decades, there has been a fall in the number of U.S. citizens interested in pursuing a career in science or engineering.[19] This decline has become a cause for alarm in U.S. governmental institutions.

> Science and engineering workers are vital to our advanced industrial society. But by the year 2010, we could suffer a shortfall of as many as 560,000 science and engineering professionals. As a result, America's economic strength, security, and quality of life are threatened.[20]

The National Science Foundation has become aware that the educational "pipeline" is failing to deliver enough students who are scientifically literate and mathematically capable to be science and engineering professionals. The problem of the "leaky pipeline" is the phenomenon whereby the number of students that complete introductory courses in science and mathematics declines steadily in the more advanced courses, with a very small number finishing their doctoral studies. The National Science Foundation, for example, has estimated that of the four million students in the 10th grade in 1977, approximately .24 percent, or ninety-seven hundred, will attain a Ph.D. in science or engineering.[21]

The pool of young people who might fill that pipeline looks very different from the white males who have traditionally filled these positions. Blacks and Hispanics, who currently make up 25 percent of U.S. school children, by the year 2000, will comprise 47 percent.[22] The change in demographics in this country means that by the year 2000, 70 percent of new entrants to the nation's workforce will be women, men of color, or immigrants. Only 30 percent of those new workers will be white men.[23] Thus, groups that historically have been underrepresented in science need to be recruited for these fields.

Awareness of the change in demographics has brought the Task Force on Women, Minorities, and the Handicapped in Science and Technology to the realization that "[o]ur pool of talent for new scientists and engineers is predominantly female or minority or disabled—the very segments of our population we have not attracted to science and engineering careers in the past."[24] In 1986, for example, a total of 3,376 Ph.D.s were awarded in engineering by U.S. universities to U.S. and

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[19] Task Force on Women, *Interim Report,* 26.

[20] Task Force on Women, *Interim Report,* 11.

[21] Task Force on Women, *Interim Report,* 30.

[22] Task Force on Women, *Interim Report,* 11.

[23] Jeffrey Norris, "Governors Issue Action Agenda on Science and Engineering Education for Women, Minorities," in *National Science Foundation News,* NSF 90–55, 13 August 1990, 1.

[24] Task Force on Women, *Final Report,* 21.

non-U.S. citizens. Of the 1,661 Ph.D.s that went to U.S. citizens, 139 Ph.D.s went to women, 25 to Hispanics, 14 to blacks, and 6 to native Americans.[25] Of course, there have always been women and men of color who have wanted to be scientists and engineers, but discriminatory attitudes and practices in the education system and professional communities have effectively locked out most of them. As long as this was seen as an equity issue no one, other than those directly affected, much cared. Now this decline in science and technology professionals is seen as a threat to America's economic strength, security, and quality of life.

In response to this threat, the U.S. Congress appointed the Task Force on Women, Minorities, and the Handicapped in Science and Technology to develop a long-range plan for broadening participation in science and engineering. That task force has completed its work, and its findings and suggested action plans have been published in two reports entitled *Changing America: The New Face of Science and Engineering—Interim Report* and *Changing America: The New Face of Science and Engineering—Final Report.* The final report, published in December 1989, includes a call to action for the nation and its political, educational, and corporate leaders. The reports give a view of the shifting demographics in the U.S. and provide statistics for the current participation of women and minority groups in science and engineering. The statistics are divided into categories of blacks, Hispanics, American Indians, people with disabilities, and white women. They do not subdivide the statistics for people of color or those with disabilities by gender. Not only does this make it impossible to consider women as a whole group, it makes women with disabilities and women of color virtually invisible, as stated in the title of the classic black women's studies text, "[a]ll the women are white, all the blacks are men. . . ." Until the women of color and women with disabilities are made visible, we can only hope that "some of us are brave."[26]

The task force recommends that the nation adopt the goal that all children, from all backgrounds, have a quality education, which includes mathematics and science education. The barriers to reaching this goal are daunting. Today fourteen million children, one-third of whom are from minority groups, live in poverty. These students are concentrated in large urban schools that have inadequate science and mathematics programs and little or no hands-on laboratory science.[27] The percentage of students, by race, who complete college preparatory programs in

[25] Task Force on Women, *Interim Report,* 27.

[26] Gloria Hull, Patricia Bell Scott, and Barbara Smith, eds., *All the Women Are White, All the Blacks Are Men, But Some of Us Are Brave: Black Women's Studies* (Old Westbury, N.Y.: Feminist Press, 1982).

[27] Task Force on Women, *Interim Report,* 17.

science, which include biology, chemistry, and physics, are as follows: 46.5 percent Asians, 18.2 percent whites, 9.1 percent Hispanics, and 8.6 percent blacks. A smaller percentage of students complete a similar course load in mathematics, which includes algebra, geometry, and trigonometry: 20.6 percent Asians, 12.4 percent whites, 6.1 percent Hispanics, and 6 percent blacks.[28] The individuals in the groups that traditionally have not been included in science and engineering are needed to fill these positions; yet, they are also the individuals with the least academic preparation.

In an effort to promote science and mathematics education and to encourage women, people of color, and people with disabilities to enter science and engineering fields, federal agencies have been expanding existing programs and initiating new programs. Focused programs, which are designed specifically to enhance the participation of those underrepresented in science and engineering, have a total budget of $209 million in 1990. Mainstream programs designed to promote science and mathematics education in general and to encourage all students to enter science and engineering careers have a total budget of nine billion dollars in 1990.[29]

One graph in the *Final Report*, based on statistics from the National Aeronautics and Space Administration, linked the number of Ph.D.s earned to the U.S. space program. The graph showed an increase in the number of Ph.D.s in engineering, mathematics, and the physical sciences after President John F. Kennedy initiated the Apollo program in May 1961. The number of doctorates awarded in these areas continued to climb until it peaked approximately a year after the Apollo moon landing of July 1969. There was generally a leveling off of the number of Ph.D.s earned for the next three years until December 1972, when Apollo 17 placed the "last man on the moon." After that there was a sharp downturn in the number of Ph.D.s earned in engineering and the physical sciences. The report states, "Student's choice of science and engineering careers is clearly related to the technological challenges on our national agenda, as . . . the history of the space program indicates."[30]

It would appear that George Bush's announcement of the goal of putting "the American flag" on Mars by 2019 is, in part, the federal government's bait to encourage young people to renew their interest in science and engineering. It may have worked for all the white males

[28] Reported in *Office of Federal Programs Special Report, Minutes of the Spring 1989 OFP Liaison Officer's Meeting*, 28 April 1989.

[29] Task Force on Women, *Final Report*, 27.

[30] Task Force on Women, *Final Report*, 25.

who entered those fields since the early 1960s, but will this strategy work for women, minorities, and the handicapped?

Given the numerous and varied gender and cultural differences between the demographic groups who have been targeted to fill the vacant positions and the traditional white men of science who hold those positions now, it is doubtful that this strategy will work. These "new faces" may not be interested in the same type of science and engineering careers that have been created by the white male-dominated system. The question arises: will the education system be able to transform "the new faces" into this type of scientist? Or will "the new faces" transform science and technology? The governmental bodies who have recognized and defined this "crisis" have a narrow conception of the problem. They see the problem as one of quality education and recruitment, which of course is a huge undertaking in itself, but there have been no questions about whether those disenfranchised groups are interested in filling the vacant positions of the retiring white males. Nor have many questions been asked as to why women are not attracted to these fields. The questions have focused on the inadequacy of the girls and women: "What is wrong with girls and women; why aren't they taking enough mathematics and science courses?" "How can we encourage women to major in science and engineering?" In other words: "How can we fix them?" Very little thought has been given to: "How can we change science, engineering, and technology, so that women are attracted to it?"

Only feminist groups have addressed how alienating science and technology have been to women. Erik Arnold and Wendy Faulkner's book, *Smothered By Invention—Technology in Women's Lives,* discusses how women have been excluded from technological fields and why some women are very put off by some uses of technology.

> On a very fundamental level, technology is alien to women because it is related to an "other" world in which women have no part and so appears mystifying and frightening. Technology is also alienating to women in the sense that the goals embodied in it are not necessarily women's goals. This is most starkly illustrated by military technology. . . .

In addition, "the actual practice of technology is often alienating to women—demanding or at least encouraging traits which leave many women cold, and which offer little promise of a more socially aware practice."[31] Social scientists have documented social influence in the making of science and technology, and feminists are continuing to

[31] Erik Arnold and Wendy Faulkner, eds., *Smothered By Invention: Technology in Women's Lives* (London: Pluto Press, 1985), 6.

explore what a feminist consciousness in science and technology would mean. Since science and technology are a reflection of the values of the people who do the work, it is encouraging to think about the ways in which a different group of people could reconstruct science and technology.

Being a feminist in science or engineering can be a very lonely and difficult identity to maintain. Given the marginal status of many women in science, engineering, or technology, it is understandable that many women do not identify themselves as feminists. Most women, whether they are students, faculty, or workers, are aware that they are a minority in these fields and that women have always been a minority or even absent altogether. One coping strategy that women employ, consciously or unconsciously, is not to draw attention to their differences. As Keller explains, if they do not make an issue of being female, then possibly it will not be held against them.

> Throughout this century, the principal strategy employed by women seeking entrance to the world of science has been premised on the repudiation of gender as a significant variable for scientific productivity. The reasons for this strategy are clear enough: experience has demonstrated all too fully that any acknowledgement of gender based difference was almost invariably employed as a justification for exclusion.[32]

If women feel uncertain of their acceptability as women, then calling oneself a feminist is taking a large risk; and most women in science do not feel secure enough to take this risk. Rosser, biologist and feminist, writes,

> It seems quite likely that many successful women scientists may overtly reject feminism or may consciously decide not to become involved with feminist issues, particularly those they perceive as affecting their professional lives, for fear it will be detrimental to their careers.[33]

Judith Moody, a geologist and long-time supporter of women in science, has noted that as women feel more secure in their roles, they are able to reflect on what their gender has meant to their work and their success, or lack of success, in the scientific community. "The normal progress for women is to reach a level of scientific maturity in which the question of feminism and science is raised. Some reach it at a very young age; some deny it; others say it's irrelevant to doing high-level

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[32] Keller, "The Gender/Science System: Or, Is Sex to Gender as Nature Is to Science?" in *Feminism and Science,* 35.

[33] Rosser, *Female-Friendly Science: Applying Women's Studies Methods and Theories to Attract Students* (New York: Pergamon Press, 1990), 109.

scientific work. . . .[34] Much of the feminist writing on science has been done by those not in the sciences but those in the social sciences and the humanities. This has raised the question of whether women working in science have gained a social consciousness of the androcentricity in science. Rosser's observations on women in science are encouraging for those interested in change taking place from within.

> In my memory, the most vocal critiques of the system, reports of active discrimination, and discomfort with perceived gender bias in scientific theories came from women well-established with the scientific hierarchy. It was often the female department chair or woman who served on the review panel of the most prestigious national foundation who most severely criticized the system. It seemed that those most successful and securely entrenched in the system could best see and understand its biases.[35]

If the change in demographics and the availability of money for programs to encourage women to enter science and engineering is going to mean more women in these fields, then the task of women's studies should be to influence these new women to be feminist scientists and engineers. This undertaking is going to require change within women's studies as well. Several women involved with the Science and Technology Task Force in the National Women's Studies Association (NWSA) have told me that they have received cool receptions from other conference participants at the NWSA meetings when they said they were scientists. Moody also has reported on prejudice against women scientists among other feminists.

> Feminists in other fields (education, philosophy, social work, nursing) can reject women in the hard sciences and engineering, stating that such women cannot possibly be feminists. So there are women colleagues who do not think that women scientists can be feminists. This rejection of women scientists by other women is probably related to their thinking that science is a male hierarchical activity. These women are misunderstanding the intrinsic integrity of basic science, independent of the person who does it.[36]

This lack of understanding and acceptance of women in science by other feminists increases the isolation and alienation these women scientists already feel due to the lack of acceptance of their feminism by male co-workers. Moody describes the difficult and lonely place this creates for women in science.

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[34] Judith Moody, "Women and Science: Their Critical Move Together into the 21st Century," *Feminists in Science and Technology* 2 (February 1989): 4.

[35] Rosser, *Female-Friendly Science*, 109.

[36] Moody, "Women and Science," 4.

> Women scientists face a multi-faceted dilemma in which they must struggle to defend their perception of feminism against the feminist notion of science as necessarily a male activity, at the same time that they must struggle to defend their new scientific approaches and interpretations in their male-defined professional world.[37]

Feminism as a social change movement needs feminists in science and technology. Feminist biologists, such as Bleier, Ruth Hubbard, and Anne Fausto Sterling, have contributed to our understanding of androcentric biological determinism because they are scientists. They needed the scientific expertise to contribute an insider's analysis of science.[38] Women scientists are invaluable to transforming science and technology because those with training in specialized disciplines can critique certain important aspects of the work, such as finding flaws in experimental designs and research techniques, and spotting biases or assumptions that have been made.

Included in the reports from the Task Force on Women, Minorities, and the Handicapped in Science and Technology is language that approaches that of feminist rhetoric in its breadth and boldness. "Changing the mathematics and science interest and achievement of a generation of students is a huge task. It requires changing America."[39] If schools and universities are going to take up the challenge, the goal of women's studies should be to provide the mechanisms for that change. Feminist scholars and scientists as individuals and women's studies programs as a whole need to find or create a role for themselves in this endeavor. If these programs are targeting and recruiting girls and women, feminists have an interest. We can provide resources as well as mold the efforts to meet women's needs and fit a more feminist vision of science, technology, and the world. The report from the Task Force on Women, Minorities, and the Handicapped calls for extensive reform of the pre-K-12 education pipeline.

Science's facade of objectivity carries over into science education as well. Almost all science classes include only facts and theories. There is resistance to including a societal context because this is seen as introducing subjectivity or information irrelevant to the science. When I teach a science class, I include the social framework from which the science comes and into which the scientific and technological information will go.. This approach means that I discuss the human and social

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[37] Moody, "Women and Science," 4.

[38] Publications by these women include Bleier, *Science and Gender: A Critique of Biology and Its Theories on Women* (New York: Pergamon Press, 1984); Anne Fausto-Sterling, *Myths of Gender: Biological Theories about Women and Men* (New York: Basic Books, 1985); Hubbard, *The Politics of Women's Biology* (New Brunswick, N.J.: Rutgers University Press, 1990).

[39] Task Force on Women, *Interim Report,* 13.

consequences of scientific discoveries and technological innovations. The reaction by the students to this is mixed. Some students respond positively, saying that this information makes the subject more relevant and interesting; others respond negatively, saying, "This is a science course. Just stick to the facts." When science education "sticks to the facts," it is doing a poor job of teaching critical thinking. Students whose lives will be influenced by science and technology, or whose work will influence science and technology, have not had the opportunity to learn the self-awareness that is necessary for independent thought. Neither have they learned the ability to compare conflicting concepts.

Women's studies has long emphasized the political nature of education and the importance of critical thinking. Bell hooks has called for a "revolutionary feminist pedagogy," which means that educators have to give students more than just information.

> Students who want to learn hunger for a space where they can be challenged intellectually. Students also suffer, as many of us who teach do, from a crisis of meaning, unsure about what has value in life, unsure even about whether it is important to stay alive. They long for a context where their subjective needs can be integrated with study, where the primary focus is a broader spectrum of ideas and modes of inquiry, in short a dialectical context where there is serious and rigorous critical exchange. This is an important and exciting time for feminist pedagogy because in theory and practice our work meets these needs.[40]

Those who are interested in transforming science need to transform science education with feminist pedagogy.

Most recruitment programs that attempt to encourage women to enroll in nontraditional fields have a liberal feminist attitude, which suggests that this is all that is needed to change the circumstances for women in science and engineering. They may be doing a disservice to women. Women's studies programs should be cautious of programs that aim only to recruit women into nontraditional fields, then leaves them there to be ignored or harassed until they drop out to return to more traditional fields. This type of neglect allows a hostile environment to destroy these women's self-confidence and self-esteem. Feminists should insist that any efforts to recruit women into science and engineering fields should also be accompanied by efforts to retain women in those fields. The goals should be explicitly aimed at challenging and changing the climate for women. An excellent resource for people engaged in recruitment and retention of women in science and engineering is Rosser's book *Female-Friendly Science: Applying Women's Studies Methods*

[40] bell hooks, "Toward a Revolutionary Feminist Pedagogy," *Talking Back: Thinking Feminist, Thinking Black* (Boston: South End Press, 1989), 51.

and Theories to Attract Students. This book should be used as a standard reference for "warming up the classroom climate for women."[41]

Women's studies scholars have been in the forefront in seeing a need for curriculum integration, and women's studies programs have been leaders in creating and promoting curriculum integration. Most of this work has focused on the liberal arts, but now we need to expand beyond the liberal arts to other colleges. Curriculum integration programs should include the colleges of science, engineering, and agriculture. Self-delusions about the objectivity of their work has led most of the faculty in these colleges to think that curriculum integration has nothing to do with them.[42] This will not be easy; if you think men are resistant to curriculum integration in the liberal arts, my experience tells me that the "defenders of the canon" will pale in comparison to the "defenders of objectivity." For when we take on science, we are no longer nibbling at the edges but have reached the center of societal control and domination. Excellent sources for information on curriculum integration in science, engineering, and technology are Rosser's books *Teaching Science and Health from a Feminist Perspective—A Practical Guide* and *Feminism Within the Science and Health Care Professions: Overcoming Resistance;* and Joan Rothschild's book *Teaching Technology from a Feminist Perspective—A Practical Guide.*[43] These volumes include references and recommendations for classroom materials, such as texts and audio visuals, and course syllabi from courses in biology, sexuality, women's health, and technology studies.

Curriculum integration, or transformation, is important in the fields of science and engineering, but women's studies needs to develop its own curriculum to include women and gender and science. This development should occur in three main areas. First, there is a need for women/gender and science and/or technology courses. Feminist scholars of science and technology studies have produced a body of literature

[41] This quote refers to a chapter title in Rosser, *Female-Friendly Science,* a book that also contains a supplemental bibliography on feminism and science, feminist pedagogy, feminist theory, women scientists, and recruitment of women scientists.

[42] For information on curriculum integration in the sciences, see Donna M. Hughes, "Toward a Feminist Teaching of Human Genetics," *Feminists in Science and Technology,* 3 (May 1989), 4 and "Curriculum Transformation of Human Biology Courses," in *Proceedings of the Conference on Women in Mathematics and the Sciences, St. Cloud State University, Nov. 10–11, 1989,* ed. Sandra Z. Keith and Philip Keith (St. Cloud, Minnesota: St. Cloud State University, 1990); Sara Coulter, K. Edgington, and Elaine Hedges, "Biology Workshop," in *Resources for Curriculum Change* (Towson, Md.: Towson State University, 1986), 52–63.

[43] Dawn Gill and Les Levidow, eds., *Anti-Racist Science Teaching* (London: Free Association Books, 1987); Rosser, *Teaching Science and Health,* and *Feminism within the Science and Health Care Professions: Overcoming Resistance* (New York: Pergamon Press, 1988); Rothschild, *Teaching Technology from a Feminist Perspctive: A Practical Guide* (New York: Pergamon Press, 1988).

so broad and vital that any women's studies program that does not have a course on women/gender and science and/or technology should be sued for academic malpractice. I have seen women and science courses have the same personally transforming and radicalizing effect on women that other women's studies courses have had. Women in the sciences and engineering need an opportunity to read feminist scholarship on science and technology. Many students are amazed that this body of knowledge exists because, prior to learning about it in a women's studies class, no one in their discipline was aware of it.

At many universities diversity requirements are being implemented as a result of the curriculum integration movement. Courses on women/gender and science and/or technology should be created to fulfill this requirement (when and where applicable). Women students in science and engineering who might not take a women's studies course may elect to take such a class to fulfill a requirement. This is a good opportunity to expose science and engineering majors to information and ideas that they will not receive in their other classes. Women's studies programs/departments that have a women/gender and science and/or technology introductory course need to move beyond the initial effort and create advanced courses in the many topics of concern to feminists in science, engineering, and technology. At the Pennsylvania State University, for example, we now have an introductory course called "Introduction to Women, Science, Engineering, and Technology" and the following advanced level courses: "Issues in the Study of Women and Science," "History of Women in Science," "Women's Health Issues," "Critical Issues in Reproduction," "Gender and Geography," and "Biopsychosocial Basis of Gender Development." Also a portion of the course "Gender, Occupations, and Professions" focuses on women's careers in science.

Second, information on women, gender and science and technology should be integrated into introductory women's studies courses, so that these courses do not reflect only the scholarship from the social sciences and the humanities. As mentioned, the feminist body of literature on science and technology has grown so large that leaving it out of introductory classes and certainly feminist theory classes is an indication of poor scholarship. It should be no more acceptable to leave out information on how science and technology affects women's lives or contributions women have made to science and engineering than it is to leave out information on women of color or lesbians.

Third, women's studies programs/departments that have an undergraduate minor or certificate in women's studies should encourage science and engineering majors to take a minor in women's studies. This goal will be difficult to achieve because many majors in science and engineering require full credit loads each semester for students to meet

minimum graduation requirements. Student's schedules have little space for electives.

Furthermore, there is a need for specialized journals in which feminist scientists can publish. The only peer reviewed journal dedicated exclusively to feminist science and technology is *Issues in Reproductive and Genetic Engineering—Journal of International Feminist Analysis* published three times a year since 1988 by Pergamon Press. Collections of works on restructuring knowledge have included articles about women and/or gender and science, and journals such as *Hypatia* and *Women's Studies International Forum* include papers on science, but feminists in science agree that we need a forum of our own for specialized discussions. The *Feminists in Science and Technology Newsletter* published by the Science and Technology Task Force of NWSA has worked to create a much needed connection among feminists in science, but the newsletter format is too limiting for more in-depth discussions.[44]

Science has long been criticized for inaccessible language, and feminists need to be aware of this; but for the exchange of information that is needed to transform science disciplines, feminists in science need a space to converse in their own language. To explore less hierarchical models of cellular organization and function, for example, molecular and cell biologists need to be able to write about their work and ideas in the language of cell biology. Such a paper may have difficulty finding a home among articles on art and literature. Feminists in science need a place where presentation of new ideas and discussion can take place in order to find new ways of looking at our own body of knowledge.

In addition, none of the women's studies textbooks I have seen has a chapter on women/gender and science and/or technology. Since women's studies has grown out of the humanities and the social sciences, most instructors of introductory women's studies courses do not have information about women and science and technology. Thus, publishers of textbooks on women's studies should be encouraged to include a chapter on women and science and technology.

Just as we need more feminists in science and engineering, we also need scientists in women's studies. Women's studies programs/departments need to explore ways to have faculty positions for women with a background or knowledge in science and/or technology. This enables feminist scientists to pursue feminist critiques of science and technology without the constraints that might be imposed on them in male-domi-

[44] *The Feminists in Science and Technology: A Publication of the Science and Technology Task Force of the National Women's Studies Association,* available from the Science and Technology Task Force, P.O. Box 6793, Houston, TX 77265–6793, is published four times a year and has been in existence since October 1987. The brief articles in this publication are not peer reviewed.

nated areas of science and engineering. A few of us who can be the bridge between women's studies and the sciences have found it very difficult, if not impossible to continue to do the science in which we were trained. This inability to combine interests across disciplines is the result of the rigidity of the structure of the university and the narrow focus that is expected of research scientists and engineers in academia. Women's studies programs also can increase the visibility of women in science and engineering or introduce the topic of gender and science and/or technology in various ways. The focus of the 1989-90 Feminist Scholars Lecture Series at the Pennsylvania State University was women and science and technology. Women's studies programs/departments need to sponsor conferences on women and science and technology so feminists can get together to discuss current topics and formulate new ideas and strategies.

Recently a new ideology, called ecofeminism, has emerged out of women's concern for the environment and a new political understanding of the destructive aspects of science and technology. The Ecofeminist Task Force of NWSA lists components that are included in ecofeminism: "Ecofeminism is about class, gender, race, nature, decentralization, bioregionalism, antimilitarism, sexualities, ritual, ecology, spirituality, conflict resolution, nonviolence, coalescence, globalism, agroecology."[45] Ecofeminism, the connection between feminism and ecology and the transformations that are brought about, is described in comprehensive and visionary language: "Ecofeminism is a term that some use to describe both the diverse range of women's efforts to save the Earth and the transformations of feminism in the West that have resulted from the new view of women and nature."[46] Ecofeminism is a vision of how humans could coexist with nature and the earth, and we should be excited by the possibilities that it creates. Much of the potential for transformation that is embodied in ecofeminism is due to its conception outside research labs and academic institutions. Audre Lorde told us that what was needed for true revolutionary change would be found outside male-dominated structures.

> What does it mean when the tools of a racist patriarchy are used to examine the fruits of that same patriarchy? It means that only the most narrow perimeters of change are possible and allowable. . . . For the master's tools will never dismantle the master's house. They may allow us temporarily to beat him at his own game, but they will never enable

[45] Linda Vance, *The Ecofeminist Newsletter: A Publication of the NWSA Ecofeminist Task Force* 3 (Summer 1990): 3. For more information about this newsletter, write to Noel Sturgeon, Center for the Humanities, Wesleyan University, Middletown, CT 06457.

[46] Irene Diamond and Gloria Feman Orenstein, *Reweaving the World: The Emergence of Ecofeminism* (San Francisco: Sierra Club Books, 1990), ix.

> us to bring about genuine change. And this fact is only threatening to those women who still define the master's house as their only source of support.[47]

One criticism of ecofeminism is its assumption that women are closer and more connected to nature than men and that women and nature are similarly victimized by male-dominated technology.[48] This conception perpetuates the ideas of biological determinism that so many feminists have criticized. Given the social construction of gender and the gender identity of nature, this assumption is the most limiting aspect of ecofeminism and calls for further analysis. If women's studies programs/departments were to invite speakers to give presentations on ecofeminism, feminists in other disciplines, as well as women in the sciences, would have an opportunity to learn and could aid in the development of ecofeminism.[49]

Although a feminist transformation of science and technology is an immense challenge, the kind of energy needed for such a task is being generated by feminist scholarship. Once people are introduced to these new ideas it forever changes their consciousness. I have found in the students who have taken my women and science class the same yearning for meaning in their lives and work that bell hooks describes in her call for a revolutionary feminist pedagogy. Some of the students come to my class on women and science disillusioned with their studies and/or research. A few have already changed majors to nonscience fields. The feminist perspective on science and technology they gain through a women's studies course revitalizes their interest in science and engineering. Also they are excited by the possibility of doing their science, engineering, or teaching in a different way. The feminist perspective seems to infuse them with creativity.

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[47] Audre Lorde, "The Master's Tools Will Never Dismantle the Master's House," in *Sister Outsider* (Trumansburg, N.Y.: Crossing Press, 1984), 110–12.

[48] Anne Karpf, "Recent Feminist Approaches to Women and Technology," in *Gender and Expertise,* ed. Maureen McNeil (London: Free Association Books, 1987), 164.

[49] The following sources provide bibliographies on women and feminism, science, technology, and ecofeminism: McNeil, "Critical Bibliography: Gender and Expertise," in *Gender and Expertise,* 225–56; Diamond and Orenstein, eds., "Selected Bibliography," in *Reweaving the World,* 310–16. For a bibliography on feminism and science that contains representative works about the lives and status of women scientists, critiques of gender bias in the sciences, and feminist perspectives on the epistemology and metatheory of science, see Tuana, "Bibliography," in *Feminism and Science,* 229–39. For two bibliographies on reproductive technology, see Gena Corea, "Bibliography," in *The Mother Machine: Reproductive Technologies from Artificial Insemination to Artificial Wombs* (New York: Harper & Row, 1985), 332–62; and Michelle Stanworth, ed., "Bibliography," in *Reproductive Technologies: Gender, Motherhood and Medicine* (Minneapolis: University of Minnesota Press, 1987), 201–18.

In thinking about where the students' enthusiasm and new ways of thinking may lead, I am reminded of Mary Catherine Bateson's words in *Composing a Life.* "It also seems probable that the most creative thinking occurs at the meeting places of disciplines. At the center of any tradition, it is easy to become blind to alternatives. At the edge where lines are blurred, it is easier to imagine that the world might be different."[50] Women studying and working in the sciences and technology are looking for something different from the androcentric science they are learning and doing. The following quote is an excerpt from a paper written by a woman working on her Ph.D. in plant physiology who took my women and science class.

> Yet, there is a frustration in studying a science, when such work in our society demands participation in a system which is exploiting that very same natural environment that I have come to love and respect. I do not want to strip the earth, or make farmland unworkable, or gain control of space in order to conquer other peoples, or create agents of biological warfare, or contribute passively to the senseless whirlpool of destruction technology seems to be creating. It is out of desire to find another way to explore and nurture our planetary life that I begin to look into feminist perspectives in science. I want to be involved in science in a non-oppressive, non-abusive manner. I'm excited by the possibilities embodied within women's studies in science, and am looking forward to writing the next page of [my] autobiography.[51]

A compelling body of feminist scholarship on science and technology now exists. Women's studies programs/departments need to take the next step in order to get this information into the minds of students so that a feminist transformation of science and technology may occur.

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[50] Mary Catherine Bateson, *Composing a Life* (New York: Atlantic Monthly Press, 1989), 73.

[51] In the women and science class that I taught, I asked the students to write their science and technology autobiographies. This is an excerpt from Winnie Devlin's paper, Spring 1990. Devlin is a doctoral student in plant physiology at the Pennsylvania State University.