Spring 2003

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Recommended Citation

Amy Lisa Graves. (2003). "Has Feminism Changed Physics?". *Signs*. Volume 28, Issue 3. 881-899.
http://works.swarthmore.edu/fac-physics/180

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Source: *Signs*, Vol. 28, No. 3, Gender and Science: New Issues<break></break> (Spring 2003), pp. 881-899
Published by: The University of Chicago Press
Stable URL: http://www.jstor.org/stable/10.1086/345323
Accessed: 09/02/2015 15:43

Amy Bug

Has Feminism Changed Physics?

Someone once said: "Scientists and prostitutes get paid for doing what they enjoy."
—Stephen Hawking, *Black Holes and Baby Universes and Other Essays* (1993, 16)

Women's work is of a particular kind . . . it always involves personal service. It requires caring labor—the labor of love.
—Hillary Rose, *Sex and Scientific Inquiry* (1987, 275)

In this article, I assess the recent manner in which feminist ideas have contributed to Western physics. This assessment is complicated, for there exists a strong tension between differently aimed critiques of the field. Among practitioners, there is an inclination to distinguish sharply between issues of "physics" and issues of "physicists." Thus, on the one hand, most physicists concede that the gender and racial composition of physics students is in need of balance. This is correlated with a mainstream movement to create race- and gender-friendly "niches" in the university for students who are "different" and with efforts by women physicists to network, mentor, recruit, and retain more women and help each other build healthy careers within the mainstream. On the other hand, most physicists presume that feminist critique is incapable of generating ideas that will make a superfluid colder, a plasma hotter, or a particle beam more intense. This is correlated with the fact that feminism has done essentially nothing to transform what one might call "orthodox physics": the body of laws, the rules of inference that relate laws to consequences,

My thanks are due to many people for their input and support, including Jeff Adams, Karen Barad, Robert Beichner, Catherine Crouch, Melissa Dancy, William Gerace, Scott Gilbert, Fred Goldberg, Zsolt Kajcsos, Lisa Kirschenbaum, Ken Laws, Priscilla Laws, Laura McCullough, David Meltzer, Joe Redish, Kristina Rolin, Londa Schiebinger, Stacy Schlau, Cindy Schwarz, Bruce Sherwood, Bonnie Shulman, Bonnie Spanier, and Joan Valles. This article is dedicated to the memory of Ann Silvi.

[*Signs: Journal of Women in Culture and Society* 2003, vol. 28, no. 3]

and the experimental methodologies by which physicists interact with and build abstractions of the natural world. Finally, most physicists would like to see more young people pursue physics and to have more sympathy for physics from an educated public. This is correlated with the existence of a physics education reform movement, which is thriving. Yet this movement is largely disconnected from the literature on race-, class-, and gender-dependence in knowledge acquisition strategies.

Getting the right number: Education reform

To the uninitiated, demographics is the only issue relevant to women in physics. This does not imply, however, that this concern is foolish or misplaced. It may be that a "critical mass" must be achieved before feminism within the field of physics can mature and proceed as in other fields. To date, women are seriously underrepresented in physics: in 1998, women constituted 51 percent of the world population, and in the United States 21 percent of the bachelor's degree recipients, 13 percent of Ph.D.s, 17 percent of assistant professors, and 3 percent of full professors (the figure did not change in the four years between 1994 and 1998). Women are 40 percent more likely than men to be hired in a part-time job (Ivie and Stowe 2000). Members of underrepresented minority groups are under-underrepresented. In 1997, fewer than 2 percent of physics Ph.D.s went to black Americans. Of these fifteen people, fourteen were men (National Science Foundation 2000). In 1996, Roman Czujko reported that the number of institutions with no women on the physics staff had dropped from 55 percent to (only!) 35 percent in a decade and that essentially no progress had been made in the number of African-American and Hispanic Ph.D. recipients.

In order to recruit and retain physics students, a physics education reform movement has taken hold. The Physical Science Study Committee (established at MIT by Jerrold Zacharrias) took up the work in the 1960s. Since 1989, Project Kaleidoscope, a national alliance of scholars, has worked to reform physics as well as other sciences, mathematics, and engineering. In 1999, the American Association of Physics Teachers (AAPT) and the American Institute of Physics (AIP) founded a Task Force on Undergraduate Physics (Hilborn 2000). The goal was a major revitalization of undergraduate physics courses. There are currently at least twenty U.S. graduate programs offering Ph.D.s in the field of physics education research (PER) and thirty-five tenure-track positions in PER for people who specialize in "how students learn physics" (Lopez and Schultz 2001).

All of the notable curricular movements have what we might recognize as "female-friendly" activities (Rosser 1990, 1995). Examples include Eric Mazur's "peer instruction" (1997), in which students interact in small groups and either agree or agree to disagree on answers; Wolfgang Christian and colleagues' "just-in-time-teaching" (Novak et al. 1999), in which students engage in face-to-face coaching on problem-solving skills, professors use their students' own words in lecture, and the program stresses the importance of the professor's learning about the experiences of individual students, not just the class as a whole; Lillian McDermott's "inquiry-based physics" (1996), a program that allows students to begin with their own speculations, make extended observations, and develop their own concepts and models to construct knowledge; and Priscilla Laws's "workshop physics" (1997), which features hands-on activities with both specialized and nonspecialized laboratory equipment and which is predicated on the idea of lecture-free "active learning" and of trusting a student to teach herself or himself additional material. In polling more than a dozen universities that offer advanced degrees in physics education, I found much sensitivity to difference, good will toward women succeeding in physics, and substantial female populations of students and postdocs. In three cases, I was told that issues of women were a side interest on which participants had done research.

In summary, the good news about PER is that many of its axioms are feminist related, for example, that the student body should be more diverse ethnically and economically and that physics should be taught to emphasize its connection to the daily lives of people in our society (Hilborn 2000). On the other hand, the axioms show a very early feminist stage of curricular reform. Sue Rosser (1997) notes that faculty who have initiated programs to attract and retain more science students, including women, typically come from the sciences and typically (though not always) do not have an extensive knowledge of women's studies and feminist theory.[1] For example, we might not hear an explicit mention of the women-and-minorities problem but, rather, a reference to "different types of students," nor would there be explicit mention of historically black or women's colleges but an oblique comment that "departments have different missions" (Hilborn 2000). In a recent article in *Physics Today,* the authors discuss how cognitive science research shaped the

[1] Priscilla Auchincloss, Karen Barad, Angela Barton, Ingrid Bartsch, Kaye Edwards, Anne Fausto-Sterling, Scott Gilbert, Bonnie Schulman, and Bonnie Spanier are just a few of many "full-fledged" scientists with full women's studies credentials who have designed science curricula.

kindergarten–grade 8 (K–8) science education reform movement (Lopez and Schultz 2001), yet there is no mention of the extensive cognitive science literature on how the gender of the child plays a role in learning behaviors.[2] In a box labeled "Are You Part of the Consensus?" there is a list of items instructors want their students to know and to be able to do. While many of these are not inconsistent with a feminist teaching of science—"Okay to take risks," "no wrong answers," or "teamwork"—none critique science and none are overtly feminist. A pedagogue taking the traditional approach—one that Karen Barad (1995) describes as a boyish, Feynmanesque, "physics is phun" one—could have penned them all. This situation might remind those with a knowledge of social history of the social action movements of the 1960s and the lack of direct attention paid to women's issues in "the Movement," which eventually spawned a separate women's movement (Curthoys 1988).

One wonders whether the reason that "the pipeline leaks" and that women leave physics at each ascending professional level is that there is a cost for being different, for speaking in a Gilligan-type (Gilligan 1982) "different voice" among one's adult peers in the scientific community (Faludi 1991). The mainstream deems it fine to offer introductory courses with alternative curricula based on different ways of knowing. It becomes progressively less fine for one to display the traditionally devalued way of speaking or knowing as one ascends the educational ladder. (Is the assumption, therefore, that these courses will get women and minorities through some immature phase so that they may subsequently use only orthodox scientific expression and practices?) This is reminiscent of the lack of women and "increasing defeminization" as one ascends in other professions, for example, in literary scholarship wherein "the price of the ticket into the professional ranks is, to use Fetterley's provocative term, cognitive and discursive 'immasculation'—learning to think and argue like a man" (Schweickart 1996, 314–15). This also resonates with recounted experiences of aspiring professionals who are nonwhite and who function in a white professional sphere: "We had to hang up our nativeness outside the door and come in and think like white people" (Goldberger 1996, 337).

If a "rising tide lifts all boats" philosophy were valid, explicit consideration of feminist ideas would not be necessary in PER. Yet the feminist

[2] Bibliographies can be found on this subject, including those by Faye A. Chadwell (Rosser 1995, 231) and Laura McCullough (2001a). In addition, see Belenky et al. 1986; Campbell 1992; Philbin et al. 1995; Giese 1996; Bauer and Shea 1999; Hodari 1999; Kimura 2000.

literature suggests otherwise. There are different male/female responses to some of the techniques and tests at the forefront of college-level physics reform (Laws, Rosborough, and Poodry 1999; McCullough 2001a, 2001b). While results remain preliminary, tests rewritten to feature female-friendly situations have been found to improve women's scores in greater proportion than men's (McCullough 2001b). Certain questions about rockets and cannonballs may give male students a gender-related advantage (McCullough and Meltzer 2001). Claude M. Steele (1997) notes that the "stereotype threat" implied in merely being asked to put one's race down on a questionnaire before taking a test depresses minority performance, yet it seems slightly to enhance majority performance, especially in mathematics. Elaine Seymour's and Nancy Hewitt's extensive work on why women and men switch out of science, mathematics, or engineering (SME) majors finds a wealth of qualitatively different responses to the same classroom stimuli, depending on the race and gender of the respondent (Seymour 1995; Seymour and Hewitt 1997). Clearly, there is an as yet unrealized opportunity for feminist ideas to join with the dynamic PER movement and infuse some vital knowledge that is rooted in feminist research.

The mainstream has recognized the fact that segregated mentoring or learning environments seem to work in physics, as shown, for example, in the stunning successes of historically black (two-thirds of all African-American physics bachelor's degrees in 1999) and women's colleges (Mulvey and Nicholson 2001). Gender-friendly niches have sprung up: special programs for minorities at major universities and labs, networking activities for graduate students on campus, and women's networking sessions at major meetings. Yet at well-known universities that have some of these outreach programs in place, it is not unusual to also see an entire semester's departmental physics colloquium schedule without a single woman speaker. A well-informed article on the subject of diversity programs at various universities recently published in *Science* magazine in a section titled "Trends in Undergraduate Education" (González 2001) describes strategies, including early involvement in research and mentoring, that allow African-American students to surmount barriers (Rey 2001). Yet, in an adjacent article on the subject of early involvement in research, it is not mentioned that this has proven good for women and minorities (Mervis 2001). In another nearby article, on the newly perceived importance of mentoring at the undergraduate through postdoctoral levels, there is no mention of issues relating to a student's race, gender, or class. The very existence of such articles is heartening. Yet the lack of these natural connections being made between articles on "regular" and "special" types of students shows that reforms, while consistent with feminism, have not been fully integrated into the mainstream.

Culture clash, culture lag

In the science wars, scholars who hope for acceptance in both feminist and science communities are sometimes caught in a no (wo)man's land.[3] People are rarely able to engage in both scientific and feminist research (Auchincloss 1996). When they do, their energies may be placed in areas that are outmoded from the point of view of mainstream feminist scholars yet radical from the point of view of mainstream scientists. Scott Gilbert (personal communication, 2001) reports that his gender-study group's influential critique of cell biology (the thrust of which is that feminist critiques are scientifically important to a field that is marred by gendered metaphors of fertilization and other processes) went unnoticed and unembraced by mainstream feminist scholars until mainstream antifeminist scholars Paul Gross and Norman Levitt targeted it (Gross and Levitt 1994).[4] A recent rejection letter for funding to bring a feminism/science performer to the Swarthmore campus reads: "The members of the Committee felt that B is somewhat dated as a feminist performer." The "dated" performance revolved around women scientists who were lost to history and of whom a traditionally educated physicist still learns nothing.

The sluggishness with which natural scientists have set about to reposition women in their history and praxis stands in remarkable contrast to the situation in the humanities. Biographical collections of women scientists published before the 1980s are rare; they have appeared in good numbers only in recent years.[5] Rosser (1988) studied the paucity of feminist papers at scientific meetings (e.g., the American Association for the Advancement of Science [AAAS]) when compared with the number at a major meeting of humanists (Modern Language Association [MLA]). She has also described the waves of feminist science curricular reform, and she

[3] The term *science wars* refers to a recent (within a dozen years) and acrimonious conflict that has arisen between some scientists and some in the field of science studies. The issues center on the validity of critiques of traditional theories of scientific knowledge—whether they are well founded and whether they are injurious to progress in science.

[4] The paper in question is Beldecos 1998. It has since been updated as Gilbert 2000.

[5] See, e.g., Rossiter 1995; Shearer and Shearer 1996; Reynolds 1999, Ambrose et al. 2000; Ogilvie 2000; Sullivan 2001.

finds that among a set of prominent national efforts, articulated goals are either at stages 1, 2, or 3 out of six sequential stages (1998).[6]

If first-wave historical feminism is the "liberal feminism" of the 1960s and 1970s (Barton 1998), which corresponds to the "liberal critique" (Keller 1987) of science that addresses skewed employment yet makes no claim that science would change with more women, then mainstream physics is still awash in the first wave. This wave might be said to have crested with the founding, in 1972, of the Committee on the Status of Women in Physics (CSWP) of the American Physical Society (APS), the world's largest professional organization of physicists. The liberal critique found its voice with papers such as Vera Kistiakowsky's (1981) "Women in Physics: Unnecessary, Injurious, and Out of Place?" As the years have passed, the slow progress of women and minorities into the professional sphere has remained a matter of concern (Vetter 1988; Fehrs and Czujko 1992). Currently the mainstream, as represented by organizations like the AIP (American Institute of Physics), the NSF (National Science Foundation), and major universities, is enthusiastically behind the idea that more women are needed at all levels. In the words of Howard Georgi, there is "unconscious discrimination" because physics selects for "assertiveness and single mindedness" (2000). Says Georgi, these qualities are stand-ins for what we really want as a community of physicists, and they map well into a set of men (a feminist might correct that to people who "do male gender" or with "male gender ideologies") who are able to do good physics.

Arguments for including women tend to be based on equity concerns, or the concern that people with good minds should not be turned away when they might be utilized in the service of physics-as-is. Arguments tend not, for example, to be based on feminist empiricist claims that only a diversely gendered group can produce unbiased results or that the problems chosen and methods used must be divested of an existing Western or androcentric bias (Harding 1987). Interestingly, cautionary words along these lines have been articulated by eminent physicists, as in: "It may be easier to adapt oneself to the quantum-theoretical concept of reality when one has not gone through the naive materialistic way of thinking that still prevailed in Europe in the first decades of this century"

[6] The six Rosser phases of curricular reform might be described as (1) absence of women not noted, (2) absence of women noted, (3) barriers to women's participation identified, (4) inclusion of historical women scientists, (5) inclusion of women and feminist perspectives in the doing of science, and (6) reconstruction and redefinition of science to be unreservedly inclusive.

(Heisenberg 1958, 202). Yet mainstream physicists are deeply troubled by feminist epistemologies of science such as those of Helen Longino or Donna Haraway that claim that a community is required in order to interpret and ratify the most fundamental acts of observation and understanding (Haraway 2001; Longino 2001). That a broader community could be generative of more good ideas is not troubling to a physicist. That it could be more objective is. As Evelyn Fox Keller notes, "a first step . . . in extending the feminist critique to the foundations of scientific thought is to reconceptualize objectivity" (1987, 238).

Such a reconceptualization is a move that mainstream physicists are loath to make. Priscilla Auchincloss recently wrote a reasoned and moderate article on physics and feminism in an APS newsletter, suggesting that "feminist studies may hold a key to the success of efforts to attract and retain women . . . create gender equitable environments . . . and to reform physics education" (1998, 15). The responses, in the form of letters to the editor, were not heartening, with one respondent titling his reply "Must We Atone for Sins of the Past?" In calling her use of the word *heresy* "overwrought," the respondent himself spins an emotionally overwrought defense of physics-as-is. Of five replies, only one respondent (male) demonstrated a working knowledge of women's studies and lamented the inability of the monumental present culture to "stop defining women as 'other'" (*APS News Online* 1998).

The anthropological concept of "culture lag" has been applied by Henry Etzkowitz, Carol Kemelgor, and Brian Uzzi (2000) to an antiquated vision that scientists hold of their own sociopolitical structure. Physics certainly lags behind most other sciences in providing a culture that proves desirable to women practitioners. The problem is exacerbated by the real culture of physics hiding behind an antiquated mask. For example, the stereotype of the lone investigator obscures the fact that scientists are members of a community (Harding 1987). Members constantly trade their stocks of "social capital" (Etzkowitz, Kemelgor, and Uzzi 2000). The "lone investigator" myth impedes recruitment and retention of women in many ways; ultimately, a successful woman must weave herself into a social network in order to establish collaborators and win support.

As a second example of a culture lag in physics, consider the widely held view that physics is the most "fundamental" of natural sciences. Barbara Whitten (1996) notes that physicists equate fundamentality with eliteness. She cites evidence that physicists take the existence of a hierarchy among subfields for granted, with work that is most fundamental (i.e., elite) associated with work that probes the tiniest, most elementary constituents of matter. In this hierarchy, it is no surprise that subfields such as biophysics and physics education are at the bottom (Whitten 1996).[7] (These subfields are interdisciplinary, accessible to more than a few experts, and contain a societal component. Not coincidentally, they attract a better-than-average population of women practitioners.) Whitten argues that a "'ladder' of fields is an extremely inadequate picture of science" (1996, 10) and much better is "a web of interconnecting fields, each with its own emergent properties [and] fundamental concepts" (11). This is a more modern and accurate view of physics. It is also more feminist if one agrees with Hillary Rose's comments that science as a top-down industry is not a fertile field for feminist reimaginings. Rose opines that "physics (is) at once the most arcane and the most deeply implicated in the capitalist system of domination. At the same time, the physical sciences more or less successfully exclude any more than small numbers of women" (1987, 272).

In summary, as if the true culture of physics were not "chilly" enough for women and minorities (Franz 1995), women are additionally encumbered by certain obsolete, inaccurate perceptions of the sociology of physics.[8] I have given just a couple of examples of such perceptions. These perceptions are, unfortunately, rooted in the imaginations of physical scientists themselves. In a recent study of imagery in standard geology textbooks, not only did photos and diagrams of people usually depict males but, while photos depicted males 72 percent of the time, diagrams/drawings did so 95 percent of the time (Phillips and Hausbeck 2001).

What next?

As meager as the feminist content sometimes is, and as divorced as it is from its identity as feminist content, I believe that feminism *has* made a significant impact on the field of physics. The specific nature of modern curricular reform and the establishment of various niche activities for women provide two bodies of evidence that support this claim. The "production of people" has traditionally been viewed as a female vo-

[7] Londa Schiebinger has also made this point, as well as cited Sandra Harding on it. See Schiebinger 1999, chap. 9.

[8] The Franz paper documents an APS/NSF-sponsored project led by Franz, Mildred Dresselhaus, and Bunny Clark to do a national survey of graduate and undergraduate students on issues of departmental climate. The results of this study have been a catalyst for positive change in faculty recruitment, creation of safe spaces, opportunities to network with other women on campus, etc.

cation (Rose 1987). While it is vital not to reinforce gender stereotypes nor to limit the scope of feminist reform by suggesting that it adhere to outmoded traditions, it would be negligent to fail to observe here that a commitment to nurturance is apparent in various key mission statements. The Committee on the Status of Women in Physics (2002) attempts "to address the encouragement and career development of women physicists"; the Society of Women Engineers (2002) hopes to provide "positive stimulation for the achievement of full potential" and "nurturance of leadership skills."

Many questions remain about the future of feminism and physics. Inspired pedagogues have already created a role for different voices and ways of knowing in introductory and niche or interdisciplinary classes.[9] One wonders, however, whether there will eventually be the same role for feminist pedagogy in every physics, chemistry, or math course. Also, while there have been a number of workers who have contributed substantially to a feminist epistemology of physics, among them Priscilla Auchincloss, Karen Barad, Evelyn Fox Keller, Sandra Harding, N. Katherine Hayles, Kristina Rollin, Sharon Traweek, and Barbara Whitten, one wonders whether feminism will someday have the epistemological relevance to mainstream physics that it does to other fields where the human connection is more manifest.

In an attempt to predict the answers to such questions, one might note that the methodologies and goals of feminism and physics actually have many similarities. Consider for example these precepts of feminism:

> Thought and action must be unified.
> Working communities are antielitist.

These have also been central principles of physics from its inception (Keller 1985): "mens et manus" (mind and hands) is the motto of MIT. (Keller, though, notes the following problems with implementation of the latter principle: ironically, the overthrow of ancient authority did not include the overthrow of male authority; and the social component of the revolution was subverted, so that social elites controlled the British Royal Society.) Both are principles of Baconian science.

On the other hand, consider the principles of feminist science, as they have been defined by Ruth Bleier (1986) and as I have listed them in the chart on the next page. In the chart, I assess whether these form part of

[9] See, e.g., Barad 1995; Rosser 1995; Schwarz 1996; Barton 1998; Shulman 2001; Weasel, Honrado, and Bautista 2001.

the orthodox practice of physics as displayed in mainstream meetings or in our mainstream literature.

Feminist Scientists	Physicists
a) Acknowledge their values and beliefs	No
b) Explore how these affect their perspectives	No
c) Are explicit and honest about assumptions and methods	Yes
d) Are responsible in language	Yes (math)
	No (metaphors)
e) Eliminate research leading to exploitation of nature	No
f) Aim for diversity among participants	Yes
g) Recognize the complexity of nature	Yes
h) Resist single-cause explanations stripped of social context	No

The poor fit between these principles and physical practice suggests that feminist principles may be so at odds with physics that to be true to both fields is to profoundly distort both of them. In the words of Harding, "neither women's activities nor gender relations . . . can be added to . . . theoretical discourses without distorting the discourses and our subject matters" (1987, 283). As I have mentioned earlier, there is an intense resistance to feminist reimaginings of orthodox physics. Steve Gensemer, an atomic physicist who is interested in issues of women in physics, has written: "Inventing a feminist version of quantum mechanics seems an incredible waste of time after all. What is needed is a way of understanding the cultural, social, gender, etc. issues in physics without throwing away our hard-won knowledge" (1998). This is a telling metaphor, one of knowledge not constructed but won, as in a battle. "Combat physics" is how women at an international conference this year described a familiar mode of scholarly interaction (Feder 2002).

If feminism is unable to further have an impact on the field of physics and if physical science continues to attract scant attention from mainstream feminists, both fields will be the poorer for it. Women's studies and feminist theory have insights to offer physics—if physicists would only permit it! Consider these five closing ideas as launching points for future thought and discussion:

First, the question "Is physics-as-is androgynous, value free, and the best physics that humanity can produce?" is not a foolish question meriting an automatic, affirmative answer. (Harding has posed a number of interesting, related questions [1991, chap. 4].) To begin with, one cannot claim that physics is "gender neutral," since feminist science studies teaches one to define endeavors from the lives of the practitioners. The very fact that women's participation in physics has lagged behind other academic disciplines and other sciences demonstrates the point. To assert otherwise is to envision a "physics" that is part of a shadow world of idealized forms, not a discipline in which real people engage. Furthermore, the physics literature is not value free. Bias is rarely as blatant as, for example, in a case history of the Hubble constant that Sharon Begley reported (2000), where one's academic affiliation determined which of two values of this important constant one espoused. Yet, when ideas are presented, no matter how neutral the language, they can make the oblique point that they are ascendant and certain others are in eclipse. When a paper begins, as so many do, "Recently, there has been much interest in X," the value of community stands out. As Bonnie Shulman (2001, 416) reminds us, based on her wealth of evidence drawn from the history of mathematics, we must teach students to "*expect* a standpoint in any scientific statement."

Second, one cannot understand the "Why so few . . . ?" problem in physics without knowing some basic women's studies, black studies, Latino studies, and so forth. For example, the gender division of labor between public and private spheres is mirrored in the work choices in the public sphere. This is integrally related to the low numbers of women in physics and, as mentioned earlier in the context of Whitten's work, the existence of "woman-rich" (e.g., biophysics) and "woman-poor" (e.g., plasma physics) subfields.

Third, physicists themselves do not speak in a single voice but use a "different voice" and different manners of thinking as the occasion warrants. There has always been a dialectic between what Karl Sterne calls "scientific and poetic knowledge" (1965). The best physicists have always kept the two in balance and known when to apply a greater proportion of one or the other. There are numerous examples of eminent physicists who have transported both terminology and substance from one discipline to another—for example, from religion to physics, or physics to society.[10] For various reasons having to do with communication and conceptualization, physicists sometimes produce creative images or narratives, much in the manner that Cindy Schwarz (1996) encourages students to do in her courses on particle physics at Vassar College. Below is an example drawn from the study of positrons and electrons. These elementary particles are "opposites" in a very rigorous sense of the word; moreover, when they meet, they annihilate in a flash of energy. Figure 1 depicts an electron and positron as belonging to the "opposite" (!) sexes. It was

[10] See, e.g., Wertheim 1995a, 1995b, 1995c, 1995d; Beller 1998; McGrail 1998; Barbour 2000.

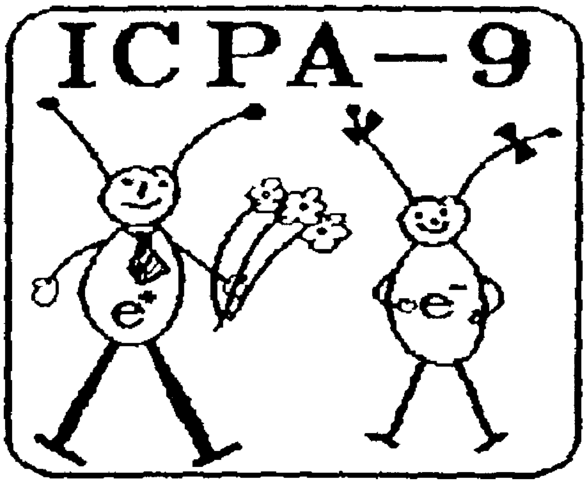

Figure 1 Electron meets positron

chosen by a leader in the field, Zsolt Kajcsos, who included it on the title page of a major conference proceedings volume that he edited (1992). Kajcsos told me that it was his little daughter who drew them—"based on the evening tales I told her." While this example may seem to reify traditionally held gender relations, it holds elements of critique available to adult viewers. (The truly "opposite" character of particle and antiparticle renders the notion of "opposite sexes" ludicrous by comparison!) This image is important in another way: it chronicles a small girl's writing herself—writing an unmistakably female image—into the story and into the physics.

Fourth, feminist epistemology of science is not monolithic. There are many such theories of scientific knowledge. Mainstream physics might be strongly persuaded by one of them, perhaps by that of Kristina Rolin (1999), a philosopher of science who has recently argued that the activities that constitute discovery and/or the formulation and justification of cognitive goals in physics are clearly embedded in the discoverer's gender identity. Rolin does not argue for relative truth of results of physical calculations or experiments, and she asserts that the overarching cognitive value in physics is empirical predictability—ideas embraced by mainstream physics. Tools of gender analysis are available to the physicist who would like to explore, for himself or herself, the distinctly gender-related elements of the discipline (Schiebinger 1999, 186–90).

Finally, ever since the inception of quantum mechanics a century ago physicists have recognized that there is a problem with the concept of "quantum reality." In the mainstream literature that addresses "quantum weirdness," some feminist contributions could be profitably included. Keller's 1985 essay "Cognitive Repression in Contemporary Physics" (chap. 7) contains a clear description of what must be dropped from the theory: an obsolete notion of objectifiability. Barad's theory of agential realism makes it clear that one may only talk of an "intra-action" between the knower and the known, that without the collaboration of the agent of observation, the idea of "objective properties" is not a sensible one (Barad 1996, 2000). A recent contribution in the orthodox literature, "relational quantum mechanics" (Rovelli 1996), is not an overtly feminist theory, yet one might argue that it is nevertheless a Rosser phase 6 theory (Rosser 1998).[11] It aspires to provide postulates from which quantum theory can be derived, or "reconstructed" in the words of Rovelli. Furthermore, and in agreement with the premises of Barad's work, Rovelli writes, "Physics is the theory of the relative information that systems have about each other. . . . I reject any fundamental distinctions as system/observer . . . physical system/consciousness" (1996, 1647). Relational quantum mechanics (Rovelli 1996; Smolin 2001) has obvious links to the "strong objectivity" of Harding (1991, chap. 6). Interestingly, while strong objectivity is so named because the traditional, nonrelative type of scientific objectivity is viewed to be weaker, just the opposite valuation is placed by Rovelli: "I want to *weaken* all physical statements that we make: not 'the spin is up,' but 'we have information that the spin is up'—which leaves the possibility open to the fact that somebody other has different information" (1996, 1646; my emphasis).

Should we be surprised that, so far, feminism has done little to accelerate the minds and hearts of physicists? Should we expect that women will continue to join the physics community and that as the population rises toward some critical mass, a feminist physicist consciousness will continue to mature? Although I have no answer, I hope that the reader has found some value in a journey through various possibilities and conjectures. In the physics community, as in the feminist community, the posing of interesting problems and the production of conjectures—even when eventually overturned—are validated activities.

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[11] See n. 6 above.

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