REVIEWS of

Educating Women for Success in Science and Mathematics (168 pages, $10.00)
by Sue V. Rosser and Bonnie Kelly (Wentworth Printing, Columbia SC, 1994)

Lifting the Barriers (112 pages, $13.95)
by Jo Sanders (Jo Sanders Publications, Port Washington, NY, 1994)

Bibliography on Gender Equity (52 pages, $??)
by Jo Sanders and Starla Rocco (Gender Equity Program, New York NY, 1994)

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by Mary Beth Ruskai

Department of Mathematics, University of Massachusetts Lowell
Lowell, MA 01854 (bruskai@cs.uml.edu) and

Department of Mathematics, Case Western Reserve University
Cleveland, OH 44106 (gh320@po.cwru.edu)

The SUNY College at Potsdam in upstate New York has a high quality undergraduate mathematics program which is particularly known for its effectiveness with women. In 1987, Pat Rogers, a committed feminist specializing in mathematics education, visited the campus to discern the reasons behind their success. She found a nearly all-male faculty and a "patriarchal" atmosphere in which the students often viewed their professors as "stern, but loving fathers".[1] Nevertheless, this program continues to bring women from diverse backgrounds into mathematics.

Lee Lorch, a white male mathematician, spent 1950-55 at then all-black Fisk University. Six of his former students, including 5 black women, eventually received PhD's.[2] No other undergraduates from Fisk, either before or after Lorch's stay, have received doctorates in mathematics.

These cases are noteworthy, not simply because they demonstrate that men can be effective teachers and mentors of women, but because, like many programs

[1] P. Rogers, "Thoughts on Power and Pedagogy", in *Gender and Mathematics: an International Perspective*, ed. L. Burton, pp. 38-46 (Cassell, 1990); See also "Transforming Mathematics Pedagogy", *On Teaching and Learning* **4**, 78-98 (Harvard, 1992); and "Student-Sensitive Teaching at the Tertiary Level: A Case Study", in *Psych. of Math. Ed.* **2**, 536-543 (1988).

[2] V. Mayes, "Lee Lorch at Fisk: A Tribute" *Amer. Math. Monthly* **83**, 708-711 (1976); and private communications with Lee Lorch.

run by women faculty or at women's colleges[3], they did *not* "tailor ... curriculum content to the particular needs of all women," as advocated by Rosser (p. v). Instead they succeeded using a traditional curriculum and sound pedagogy combined with a strong commitment to nurturing the talent of all their students.

It is widely believed that our current approach to math and science education was developed to suit the needs of males, who constitute the bulk of the science and engineering work force. However, closer examination suggests that this system was developed without much attention to pedagogy and that it is often ill suited to men as well. Indeed, only 26% of boys in the US even study high school physics[4] and the drop out rate among those who go on to study science and engineering is high for both sexes. The current gender imbalance may be the result of a culture in which more males survive a deficient education system. Potsdam is not the only example of a program designed on pedagogical grounds whose striking effectiveness with women seems almost incidental. For over 50 years, R.L. Moore taught mathematics using a unique approach (now known as the "Moore method") in which he eschewed both textbooks and formal lectures while stimulating and guiding students to self-discovery of mathematical results. The result was a large number of highly successful doctoral students including at least four women, the first in 1922.[5]

By contrast Rosser's approach is based upon a model in which not only pedagogy, but science itself must be "redefined and reconstructed". Although Rosser admits that "this critique has been developed most extensively for the biological sciences", she asserts that it has "high applicability to ... physical sciences" without offering any evidence to support this. None of the five plenary speakers associated with her project has any expertise in mathematics or the physical sciences; all five have backgrounds in Women's Studies and/or Biological and Health Sciences. Moreover, the brief section on contributions of women scientists contains serious misinformation about the accomplishments of the women mathematicians and physicists mentioned.[6] While Rosser's book is not intended to be a definitive

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[3] See, for example, R.J. Hughes and C.Sadosky, "What Works: Successful Programs for Women in the Mathematical Sciences" Symposium at the AAAS meeting in Atlanta (16-21 Feb., 1995).

[4] D. Bernstein and R. Czuyko, American Institute of Physics report (199?).

[5] L.S. Whyburn, "Student-Oriented Teaching--The Moore Method" *Amer. Math. Monthly* **77**, 351-359 (1970); and D.R. Traylor, *Creative Teaching: Heritage of R.L. Moore* (Univ. of Houston, 1972).

[6] A list of 11 women "inventors" on p. 24 incorrectly attributes "nuclear fission" (popularly known as atom-splitting) to Madame C.S. Wu and "calculations to split the atom" to Maria Goeppert Mayer. If any one person is to be credited with the discovery of nuclear fission, it must be Lise Meitner, who is not even mentioned. Her theoretical work, done in exile in Sweden in 1938, convinced the scientific community that nuclear fission could explain the experimental results of her former collaborator, Otto Hahn, and stimulated further experiments by others confirming fission. Mayer, who was only peripherally associated with the Manhattan Project, received the 1963 Nobel prize for research done in 1950 in which she demonstrated that the so-called "shell

history of science, some of these errors are so egregious as to raise serious questions about both the quality of her scholarship and her interest in the physical sciences.

It is curious that, although both Rosser and Sanders point out that efforts to improve education for females inevitably benefits male students as well, they focus on gender-specific strategies rather than trying to identify more general pedagogical factors which are important to women's success.

None of the three books under review is scholarly. Sander's two books are essentially resource lists, augmented by a brief, but insightful, preface to *Lifting the Barriers.* Rosser's book is a manual for training teachers to implement a model she has long advocated, but whose validity is not well-documented. Although these books contain some good ideas, I found them rather superficial. For example, it is surely worthwhile for teachers to pay more attention to the contributions of women scientists; however, no evidence is presented that the inclusion of such materials affects women's performance in science courses. By contrast, there is little discussion of non-gender-specific techniques, such as student empowerment through participation and self-discovery, despite growing evidence of their effectiveness. [1]

Lifting the Barriers claims to contain "600 tested strategies that really work". In fact, the book is simply a compilation of things that 200 educators associated with Sanders' "Computer Equity Project" tried. There are no reports of comprehensive studies to support anecdotal claims of success. Many of the supposed 600 strategies are simply variations on a much smaller number of themes, e.g. parent and mother/daughter events. All the descriptions are short, often one sentence, and not accompanied by a careful discussion of issues that might arise with implementation. It is not clear for whom this book might be useful. Those who find these suggestions unfamiliar should have a more thorough analysis of each strategy.

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model" could be used to explain nuclear, as well as atomic, energy levels. Wu is an experimental particle physicist who is best known for performing a critical experiment in 1957 to demonstrate that parity (left/right-handed symmetry) is not conserved when a neutrino decays.

Rosser also asserts that Anna Pell-Wheeler "invented functional analysis". Pell-Wheeler's biographers [L.S. Grinstein and P. J. Campbell, *Hist. Math.* **9**, 37-53 (1982); see also pp. 241-246 of their book *Women of Mathematics* (Greenwood Press, 1987)] state that she herself "considered her work to be centered on 'linear algebra of infinitely many variables,' a *branch* of what is known today as functional analysis" and that "she began her investigations at a time when functional analysis was emerging as a distinct area". Given the earlier work of Banach, Hilbert, Schmidt and others, the claim that Pell-Wheeler "invented functional analysis" is absurd and does a disservice to her fine mathematical work which was recognized in many ways, including the honor of delivering the 1927 Colloquium Lectures to the American Mathematical Society.

Together with Starla Rocco, Sanders has also edited a bibliography of gender equity resource materials. The introduction claims that the authors conducted a survey of professors of education in which "lack of materials was one of the most frequently cited reasons for failure to teach student teachers in math, science and technology about gender equity." This is a disturbing finding to which a bibliography is an entirely inadequate response. As with any printed list, material rapidly becomes out-of-date and the authors freely admit that they did not have the resources to check accuracy. For example, despite a 1994 copyright, the book contains obsolete information about the Association for Women in Mathematics which moved its offices from Wellesley college to the University of Maryland[7] in January, 1993 and makes no mention of its widely acclaimed *Careers that Count* booklet which has a 1991 copyright. If this type of bibliographic resource material is useful to educators, it is surely time to make an up-to-date version available electronically.

Rosser and Kelly's book is based upon a teacher-training project Rosser directed. Over 30 pages are devoted to describing how to organize a plenary conference, 10 pages to a "Phase Model for Transforming the Natural Sciences" and less than 25 pages to "teaching strategies". The last, which forms the heart of the book, is a list of 17 slogan-type strategies, none of which is developed in depth. While I would question the centrality of most of these strategies, many would enhance a pedagogically sound program. However, some of them may be counter-productive for reasons I will discuss below.

My criticisms might be less severe if Rosser could provide evidence for the success that she claims. Because this was a teacher-training project much of the evaluation process was concerned with changes in instructor attitude rather than student achievement. Student retention was measured by a criterion of subsequent course enrollment so weak that both participants and non-participants reported retention rates over 95%. Student achievement was measured by comparing average grades in courses taught by participating teachers before and after the project. Thus, it is unclear whether the modest gains reported reflected student improvement or changes in the instructors grading criteria. The book also summarized narrative reports from site visits; but the only consistent pattern seemed to be that group work was effective -- a finding that has been confirmed by many educators not directly concerned with gender issues.

Let me begin a more detailed critique by supposing that someone had written "Although men often enjoy reading, literature, or poetry for their own sakes, and show great sensitivity to the beauty of good writing, women do not have much appreciation for the subtleties of the written word. Nevertheless, they can

[7] Association for Women in Mathematics (AWM), 4114 Computer and Space Sciences Building, University of Maryland, College Park, MD 20742-2461 (301-405-7892; awm@math.umd.edu).

learn to read and write when taught properly. It is important to motivate women by pointing out the practical applications of literacy such as the availability of information in newspapers, and the need to be able to read the instruction manuals for household equipment. It is helpful to include examples from fields which interest women, such as cookbooks and child care references." Absurd and offensive as this may sound, it is analogous to the advice in Rosser, who is not alone in suggesting that women are only interested in practical applications, but not in the 'technical aspects' of science. While Sander's echoes these themes in her preface to *Lifting the Barriers,* she also includes a thoughtful discussion of the dangers of strategies which reinforce gender stereotype (pp. 14-15, "The Equity Trap").

Rosser (p. 37) claims that Harding[8] has shown "that girls who choose to study science do so because of the importance of the social implications of the problems science can solve." However, this claim contrasts starkly with other surveys and with the virtually universal acknowledgement among women scientists that we *enjoy* it.[9] The disparaging connotation that is often attached to the observation that boys are interested in the technical aspects of science ignores the fact that there is creativity and beauty within, and unique to, science. To insist that women cannot be interested in "science for its own sake" is to deny that science also has aesthetics and that women can appreciate beauty in this sphere as well. Perhaps the biggest loss of our culture is not the career opportunities, but the refusal to allow women to share the pleasure they find within science. Just as most of us can appreciate music even if we do not have the talent to become concert pianists, most girls do have a natural appreciation for the beauty of science and mathematics which is stifled rather than nurtured.

In our present cultural milieu, it is hardly surprising that many women, especially when interacting with non-scientists, emphasize the potential beneficial applications of their research. However, it is important to remember that the "women lib" movement which emerged in the US in the 60's and 70's strove to do more than expand career opportunities for women. It also challenged the idealization of a self-sacrificing woman whose concern for others was so paramount that her own personal development suffered. Women's horizons were allowed to expand beyond home and family to include art, music, politics, and sports as well. It is essential that these expanded horizons do not stop at science and technology, but acknowledge the legitimacy of women's presence in these spheres without requiring additional justification on utilitarian or humanitarian grounds.

By contrast, attitudes about the suitability of women's participation in

[8] Despite a library search, e-mail inquiries and a fax from the author, J. Harding, referring me to the ERIC clearing house (which I searched electronically), I was unable to locate a copy of the article Rosser cites.

[9] See, for example, the statements of the 20 women included among the 75 scientists interviewed by Sigma Xi on its 75th Anniversary. *American Scientist* **76**, 450-463 (Sept.-Oct., 1988).

sports has changed dramatically since the time when they were regarded as too "delicate" to engage in strenuous physical activity. It is now well-documented that regular physical exercise has significant health benefits for women of all ages. Yet virtually no one *maintains* a regular exercise program *solely* for medical reasons. Those who continue to exercise do so because they have found an athletic activity which they enjoy.

The inclusion of practical applications can often add interest and insight to a scientific discussion. However, this should only be used to enhance science pedagogy; it should never be allowed to reinforce the stereotype that any intrinsic interest in science is unfeminine.

Unfortunately, some of Rosser's strategies (e.g., 10, 15, 17) seem designed to accommodate such stereotypes in ways that are fundamentally unsound. It is certainly true that a single laboratory experiment may be artificial and give a misleading picture about complex phenomena. Therefore, good pedagogy will show how scientific methodology uses multiple experiments to provide deeper understanding of complex phenomenon. Rosser emphasizes the need to put experiments in context in ways that appeal to women while neglecting the broader issues of sound experimental design and interpretation. She even advocates "combin[ing] qualitative and quantitative methods of data gathering" (p. 39), instead of discussing the limitations of each and carefully delineating those circumstances in which one or the other may be more reliable. Her slanted approach is particularly disturbing because Bleier and Hubbard, whose cited work is fundamental to Rosser's own "phase model", have established that bad scientific methodology is responsible for much of the flawed social and biological research that has been detrimental to women.

Rosser also claims (p. 41) that "it is essential that females be paired with females as laboratory partners." While there is no doubt that *some* female-male pairings may be detrimental to women, it is hard to believe that any woman's scientific career would be enhanced by *never* interacting with those men who will someday be her colleagues. By contrast, Sanders (p. 14) recognizes that "If boys' behavior makes it difficult for girls to learn well, the solution is to improve the boys' behavior, not segregate the girls in some kind of protective cocoon". In view of the increased use of group work, it is unfortunate that neither author provides educators with a thorough analysis of the issues involved in changing behavior patterns (possibly of both sexes) so that classroom and laboratory environments are conducive to healthy collaborations and interactions.

Instead, Sanders (p. 13) claims that it is well-established that women learn better in single-sex environments. It is true that many women's colleges do have well-documented records of success in developing women scientists[10] and that some teachers have reported success with single-sex classes. However, I am aware of only one study which compared coed and single-sex classes in otherwise identical learning situations.[11] The differences were few and small, leading the authors to conclude "The results of the study do not support the creation of all female classes in coeducational schools as a way to boost mathematically talented girls' self-perception and achievement." This raises the question of whether the all-female environment is essential to the successful programs at women's colleges or whether their strategies can be transferred to other types of institutions. The experience of Lorch, Moore, the Potsdam faculty and others strongly suggest that the answer is yes.

Finally, I would like to comment on some ethical issues. In rightly advocating a de-emphasis on military applications, Rosser refers (p. 43) to "experiments that seem useful ONLY for calculating a rocket or bomb trajectory" (emphasis added). However, even the scientifically naive can understand that the physical principles elucidated by such experiments will also apply to commercial aircraft, communications satellites, baseball trajectories, and automobile accident reconstruction. Furthermore, some of the underlying physics and mathematics may well apply to such less obviously-related phenomena as blood flow to the heart or crop irrigation. Ethical dilemmas arise because scientific principles cannot be divided into a "good" part which can only benefit mankind and a "bad" part which leads only to destruction. The same kinds of partial differential equations can be used to model such diverse phenomena as explosions, blood flow, weather, and the stock market. Many scientific discoveries have had unanticipated applications long after their founders died. This breadth of scientific applicability has often been used to avoid ethical responsibility; however, failure to recognize its validity will not lead to resolution of complex ethical dilemmas.

A more compelling, gender-free, reason to be circumspect about introducing military applications into the educational process is simply that society should not want to attract to science those who would be motivated by its destructive potential. However, there is another important ethical aspect to science and engineering education with gender implications that is rarely discussed.

Many science and engineering activities, such as designing bridges and airplanes, have a direct impact on our welfare. Those of us who educate potential

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[10] See, for example, N.R. Sharpe, "Sisters Spell Success in Science" *Mount Holyoke Alumnae Quarterly* pp. 26-28 (Winter, 1995), based on based on the study and technical report "Baccalaureate Origins of Women Scientists: Trends and Transitions"; or J. S. Sebrechts, *Journal of NIH Research* **4**, 22-26 (1992), but note that Sebrechts' article seems to be Rosser's source for the historically inaccurate information described in note 6.

[11] S.M. Strauss and R.F. Subotnik, "Gender Differences in Behavior and Achievement: A True Experiment Involving Random Assignment to Single Sex and Coeducational Advanced Placement Calculus Classes" *AWM Newsletter* **24**(3), 12-25 (May-June 1994); based upon a final report to the NSF of a study at Hunter College.

scientists and engineers have a responsibility to maintain standards which result in highly qualified graduates. However, this does not justify an impersonal "weeding" process in which large lectures and tricky examinations culminate in an initiation ritual marginally related to education. Instead, it is our responsibility to first provide students with the kind of sound education which will give them the skills and knowledge needed for the positions they seek. Only then do we have the right and duty to insist that students demonstrate in a fair assessment process that they have attained the necessary high standards. The limited data available[12] strongly suggest that those women who self-select to study science and engineering have, on average, higher grades than men. The cultural process which directs more men to engineering results in a subgroup of (almost exclusively male) students who graduate despite poor grades. It is in society's interest, not only to encourage outstanding women to doctoral study in science, but to replace the marginal C-D men who receive bachelor's degrees by capable B-C women. Providing more women with the educational resources to pursue careers in science and engineering is a matter of social responsibility as well as gender equity. The accuracy of predictions about our future needs is now the subject of considerable dispute. What is certain, however, is that it is in society's interest to attract and educate the best from every gender and ethnic subgroup.

Achieving this requires that science educators have access to the best possible information about pedagogical advances and their implications for women. The books under review make only a small contribution to this effort. Much more needs to be done.

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[12] See, for example, R.J. Hughes, "Calculus Reform and Women Undergraduates" in *Calculus for a New Century*, ed by L.A. Steen (MAA, Washington, DC 1987) pp. 125-129; or a more recent unpublished study of engineering undergraduates at the University of Massachusetts Lowell.