Teaching Mathematics Effectively and Equitably to Females

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The Current Situation

The nation continues to be troubled by the apparent lack of mathematics achievement by girls and by the lack of involvement of women in math and science related careers. While the gap between male and female achievement is finally slowly lessening, females still take fewer and less advanced math courses than males, and women are still poorly represented in careers requiring sophisticated mathematical knowledge. Efforts to close the gap altogether must be intensified. If the United States has a moral commitment to provide equal access and equal education to both sexes, it has an economic imperative to increase the size of its mathematically and technologically skilled work force, and to provide its youth with the education required for financial self-sufficiency.

This monograph reviews the ways that girls are treated in general, and the nature of mathematics education, in today's school, in order to identify ways to increase both their interest and achievement in mathematics.

Achievement History

Age Variables

Although America 2000 raises the issue of math and science achievement for females as a national concern, it is a concern shared by most nations. In an analysis of the mathematical achievement of twelfth grade girls in 15 countries, researchers found that in all but three countries—Thailand, British Columbia (Canadian province), and England—girls were less successful than boys (Hanna, Kundiger, & Larouche, 1990). These findings seem to universally reflect the sex stereotyped perception that girls can't do math. While the study could not directly attribute achievement to any contextual variable (female teachers, school organization, expectations for the future, home support), it suggests that these variables interact with other societal factors to discourage females from mathematics.

Moreover, the study showed that while girls often underachieved, their area of underachievement varied by country. Since the gender differences vary from country to country, and since it is unlikely that biological gender differences vary from one country to another, the data tend to discount theories (Gershwind, 1984; Benbow & Stanley, 1982) that attempt to explain male math superiority on the basis of biology.

Research on mathematics achievement of girls has surfaced several important points that seem to indicate a strong pattern of socialization to mathematics success or failure. As most research and writing indicates, it is not until age 10 that any gender difference in math achievement is found (Callahan & Clements, 1984; Dossey, Mulis, Lindquist, & Chambers, 1988); until this point any differences favor girls (Brandon & Newton, 1985).

However, once students reach middle school, the achievement levels of females decline. By age 17, males scored higher than females on all four cognitive areas, with males scoring considerably higher as the cognitive level of the questions increased (Fennema & Carpenter, 1981).

Cultural Variables

It should be noted that gender differences in mathematics achievement are smaller than differences between race. Asian students as a group outperform whites, while both groups outperform Latino or African American students. African American and Latino students have made greater gains in mathematics achievement between the National Assessment of Educational Progress assessments of 1978 and 1982 (Lappan, 1988), however. Since different tests show differing degrees of sex and race differences, any examination of any group's achievement based on scores needs to carry a cautionary note. For example, the mathematics section of the Scholastic Aptitude Test (SAT) produces more gender differences than does the quantitative portion of the School and College Aptitude Test (Campbell, 1986). Moreover, tests are developed out of a set of cultural assumptions, including perhaps an assumption that girls cannot achieve in mathematics. It is, therefore, relevant to ask questions about what the criteria for achievement are, what the assessment is really measuring, and who benefits from that assessment. As Stanic (1988) points out, mathematics education does not solely count for the differential achievement. It is often the measurement tool itself that creates the disparity in achievement.

The examination of mathematics achievement for females also needs to be examined within the context of race and socioeconomic status. For instance, the generalization is that expectations for females are lower (Stage, Kreinber, Eccles, & Rossi Becker, 1985). However, Campbell and Shackford (1989) point out that in some urban high schools, young women of color feel math teachers expect and demand more from girls. Similarly, socioeconomic status has been a major factor related to achievement; students from high SES families, schools, or communities perform best (Lockheed, Thorpe, Brooks-Gunn, Casserly, & McAloon, 1985).

The inter-relationship of these variables needs to be considered in any effort to understand mathematics achievement as well as the socialization patterns that impact on that achievement. Butler, in a discussion of African American girls and schooling reiterates that "while gender discrimination affects all girls and women and while race and class discrimination affects all minority groups there are differential effects. The combined effect (race, gender, and class) is greater than the sum of the individual parts. It is apparent that a diverse population requires diverse strategies if progress toward implementing reforms for equity in education are to be realized" (Butler, 1987, cited in Campbell, 1991).

It is, also important to note that any relationship between sex or ethnicity and achievement is correlational. As Campbell (1986) points out, "Based on a finding of differences, one may not conclude that being black, Hispanic, or female causes any difference. The different backgrounds and experiences of girls and minorities and of boys and white students can—and most likely do—affect achievement." Thus, achievement can be examined within the context of what is taught to whom, how it is taught, and how it is experienced.

Analysis from Research

Citing a study of 1,364 students in 74 high school classes (Senk & Usiskin, in Stanic, 1988), Stanic cites the finding that males and females were equally able to write geometry proofs. Proof writing requires spatial abilities and is also a high-level cognitive task—two areas in which males tend to score higher than females on standardized tests. The researchers point to the need to compare the test items with students' experiences, for "when test items cover material that is taught and learned almost exclusively in the classroom, no pattern of sex differences tends to be found."

Research has attempted to provide an answer to the gender disparity in mathematics achievement. While some researchers (Benbow & Stanley, 1982) argue for a biological explanation, others focus on environmental factors, including differential course work, home support, the sense of math as useful, the sense of math as a male domain, or the teacher-student interaction (Pallas & Alexander, 1983; Belz & Geary, 1984; Fennema & Sherman, 1978; Fennema & Peterson, 1985). And, like the Gender and Mathematics international comparison, these environment-focused studies do not isolate one specific variable, but rather show a strong interconnection between mathematics achievement and sociological and attitude variables.

Achievement Trends

A recent meta-analysis of mathematics achievement (Freidman, 1989) points to an emerging trend—gender differences in favor of males are decreasing over time. Likely, this lessening of the gap is the beginning of a response to the work done in previous years on curriculum development and teacher and student attitudes toward mathematics, and to the gender equity efforts begun in the late 1970s. Since change is a process that occurs over an extended period of time, mathematics research that examines differences over time is a good indicator of that change.

Freidman's research was a meta-analysis of recent studies of gender differences in quantitative tasks. It focused on the years during which patterns of female achievement change, and so excluded both preschoolers and college students. Ninety-eight studies published after 1974 were collected. These included 36 high school studies, with studies of younger students predominating.

The results of Freidman's analysis were then compared to the meta-analysis of the studies on quantitative skill done by Maccoby and Jacklin in 1974. These comparisons, together with comparisons of Scholastic Aptitude Test effect sizes over the years, show two important things. First, the average gender difference in achievement is very small, and second, gender differences in performance are decreasing over the years. Her research supports earlier meta-analyses by other researchers (Hyde, 1981; Fennema & Sherman, 1978; Tartre & Fennema, 1991).

Since the gender difference in favor of males is decreasing over a short period of time, an exploration of environmental/socialization factors for such gender differences seems merited. It is environmental, not biological, changes that have occurred during this time. Freidman's meta-analysis gives further weight to the argument that it is not the female student herself, but rather the classroom and social structure, that limit girls' active involvement in mathematics.

Higher Education Experience

Despite the slowly closing gap, males continue to earn more bachelor's degrees in math and science. Between 1974 and 1984, 89 percent of males and only 0.5 percent of females earned engineering or computer science degrees; 5.6 percent of men and 2.6 percent of women earned physical science and math degrees, and 7.8 percent of men and 4.8 percent of women earned degrees in biological sciences. However, only 8.5

percent of men and 25.5 percent of women earned education degrees, and 2.9 percent of men and 13.1 percent of women received degrees in health science services (Adelman, 1991).

Women's experiences are different from those of males, and those experiences are “unsatisfactory in ways not recognized by most university teachers and critics of education policy” (Kramarae & Treichler, 1990). They argue that women experience the academy differently for several reasons: curricula that largely excludes the experiences of women, professional advising that restricts their options, and male control of classroom talk. Thus, the messages and socialization patterns established earlier continue to play out in post-secondary education and careers.

Gender Research

As social scientists were exploring the ways that differential treatment of males and females caused the differences in their mathematical achievements and interests, physiologists have also been researching whether the differences are sex-linked. Aiken (1987), in a review of the research literature, has asserted that it must be concluded that both heredity and environment are important in shaping mathematical ability.

While female brains develop differently, and there seems to be some indication that males develop right brain functions earlier than females (Cane & Cane, 1991), this research is still tenuous and needs to be explored within the context of socialization of infants and young children.

An interesting finding in terms of the area of mathematics achievement and gender may surface from recent brain research. It seems that the socialization of young girls may, in fact, interfere with the initial development of brain patterns that enhance mathematics learning. For instance, studies have shown that an enriched environment produces distinct physiological changes within the brain that enhance learning. Thus, if a brain receives repeated stimulation, it develops strengthened neurological pathways enabling faster and more complex processing of information. At the same time, chemical changes within the brain further increase the capacity to process complex information. The more a brain pathway is used, the faster and more permanently does that synaptic activity happen—like a path in the woods, the more it is used, the deeper the path (Clark, 1983; Morrel & Norton, 1980, cited in Hensel, 1989). For girls and for economically disadvantaged children of both genders, who are not exposed to mathematics as play, these neurological pathways may take longer to develop than they would in boys.

Equally important from a physiological perspective is the limbic system in the midbrain, which acts as the emotional center for humans. Although emotional responses are usually viewed from a social perspective, emotions have a biochemical affect on the learning process. This emotional center can either inhibit or enhance memory and learning, since it combines all experiences of an individual to provide that learner with a frame of reference through which he or she interprets the world. Depending on the affective feelings of the individual as influenced by the environment, this center can release neurotransmitters that affect the actual learning. If a person experiences joy, the limbic system releases neurotransmitters that increase the speed of learning. Stress, however, activates different neurotransmitters and shuts down the brain's capacity to retrieve or process data (see Hensel, 1989). While numerous examples exist of a student's inability to learn a specific process despite repeated attempts by the teacher (often reiterations of the same problem presented in the same way), very little connection has been made with this physiological phenomenon, which says that the student *physically* may not be able to learn at that moment. Should the stress be removed and the problem presented another way, the limbic system can again assist in the learning process.

Student Gender Differences

Learning Styles and Classroom Behavior

Impact of Socialization

Throughout their learning girls are encouraged to be passive, caring, to take no risks, and to defer to male voices in the public discussion. They are also given the message that math is for males. Such an orientation obviously has an impact on how they learn and behave in school.

As children grow, they are often unconsciously encouraged to adopt sex-stereotyped roles. Boys are encouraged to play with action toys, learning about mathematical concepts. Young girls are encouraged to learn to express themselves verbally, with little opportunity to experience those math concepts (velocity, angles, three-dimensional configurations) that become the core of mathematics. While still learning language and discourse skills, young boys, as opposed to young girls, learn to be comfortable with a physical world, and to be able to translate that physical world into the discourse of the math class. For boys, mathematics is not just an abstract concept, but a firm part of their experiential base, and they can visualize math processes. For instance, young boys can create a three dimensional object "in their heads." Young girls often need to try to construct this knowledge without a base in reality; it therefore seems to have no relevance to their own experiences (Hensel, 1989). Girls try to create a process they cannot "see" by using words rather than mental pictures, using the one skill they have developed.

Differential Discourse Styles

For many females, mathematics language, its discourse mode, and the dynamics of the classroom are oppositional to the way they are socialized to interact and communicate. On the other hand, males socialized toward an individualistic perspective may be more comfortable with "interaction based on individual expertise and presentation and elaboration of abstract concepts" (Kramarae & Treichler, 1990).

Research over the past ten years has challenged the assumption that teaching to men and women is experienced in the same way (Weiler, 1988; Sadker & Sadker, 1985; Weis, 1988; Gabriel & Smithson, 1990). Indeed, no two students receive the same learning experience in the same way. Compounding learning differences are the sex role stereotypes that define expectations for males and females, and their membership in different race, socioeconomic, and ethnic groups.

For example, while the women in Kramarae and Treichler's study of college students made explicit statements about the structure of the learning process, the men's focus on the importance of debates about ideas suggests there are two discourse models operating. The women place importance on mutual support and the building of collaborative knowledge. Male priority is based on individual expertise and the presentation and debate around abstract concepts. Although how participants in a class talk actually shapes the discourse and discovery process, traditional nonpersonal hierarchical classroom interaction tends to support the male discourse model.

Further, while males engage in the discourse, females write papers. This may enable women to earn good grades, but they miss out on mastering the thought processes required for a verbal debate. Additionally, the role of writing is played out differently in the humanities and social sciences, where females have long been more active and comfortable. The role of writing in mathematics for the most part may not play the connective role it does in other areas. Felt knowledge comes from the interaction with others in the mutual construction of knowledge. If female students are excluded from that construction they cannot move into the conversation later as part of their careers. For many women, then, the discourse of mathematics and science can become another equivalent of “sports talk” which remains within the male domain.

For those women who attempt to enter into the discourse as equals by adopting a male discourse model, the response is no better. Women are often penalized for attempting to participate in the “male domain.” Often the perception of behavior is confused with actual behavior, based on sex role stereotypes. While a male might be called ambitious, assertive, and independent, a women displaying the same behaviors is often labeled aggressive, pushy, and argumentative. Studies continue to show that when women and men exhibit the same behavior, that behavior is devalued for women (Pearson, 1987).

Barbara McClintock, winner of the Nobel prize in science for her research on the genetics of corn, talked of her research as communication with her work, “you had to have the patience . . . to hear what [the corn] has to say to you and the openness to ‘let it come to you'“ (Belenky, Vicker-Clinchy, Goldberger, & Tarule, 1986). When applied to mathematics, this sense of connected discourse makes the field come alive for many women. For instance, adding discussions of “responsibility and care” to the teaching of calculus enabled two professors to increase the interest and achievement of females in the discipline. These ranged from the large issues of population growth, pollution control, and infectious disease to the more familiar issues such as "How would you work out how many great-great-great-great grandparents you had?" (Barnes & Coupland, 1990).

Although considerable research is aimed at "solving the problem" of female underachievement in mathematics, few interdisciplinary applications exist that draw on anthropology, sociology, or linguistics to examine the context for this mathematics "problem" and to explore long- and short-range strategies to respond. For too many, the question of girls and mathematics achievement continues to focus on the question of why girls don't achieve rather than what is it in the classrooms or the culture that creates barriers to math success for girls. Or, as Borasi (1991) asks, "How could school mathematics be changed in order to become more appealing to women and better accommodate their thinking and learning styles?"

Attitudes toward Mathematics Learning

Math as a "Male" Subject

The issue of self selection—making choices to opt out of activities that put girls into settings where they can develop an understanding and appreciation for math and technology—may well be in place by the time girls reach preschool. The strong social messages remain that technology, mathematics, and science are nontraditional arenas for girls. Girls, feeling less confident in their abilities in these areas, self-select out; both boys and girls define science and mathematics as "male" as early as the second grade (Klein, 1989). Unfortunately, attitudes and behavior that reinforce children's math perceptions often remain unconscious and unacknowledged by classroom teachers or parents, themselves the products of a sex role stereotyped socialization.

Both male and female students in one state study agreed that math, science, and gym favored males ("boys like gross things" and "girls could care less about spiders, ticks, and mice"). Their explanations for this were traditionally gender-stereotyped: girls only need math for grocery shopping; girls avoid advanced computer classes because they "don't want that brainy image" and "girls can't get into science the way boys do because it just doesn't have anything to do with their future or careers" (Michigan State Board of Education, 1991).

This perception is backed up by the finding that liking mathematics is a primary factor in whether or not students do well. Students who say they like mathematics perform better on math tests (Lockheed, Thorpe, Brooks-Gunn, Casserly, & McAloon, 1985). The liking or not liking of a particular class is based in part on a student's feelings of success within that class—feelings based not just on academic achievement but also on their felt experiences in the class. Campbell and others have found that girls' confidence in themselves as math learners, their perception of math as a difficult subject, and their view that math is a male activity, all have impact on girls' attitudes, achievement, and participation in advanced courses (Campbell, 1986). In a longitudinal study of sixth, eighth, tenth, and twelfth grades, Tartre and Fennema (1991) found that, for girls, viewing math as a male domain was correlated to math achievement. Girls—for instance those in single-sex schools or in out-of-school math projects—who do not see mathematics as an exclusively male domain tend to have higher math success. When this dynamic is changed to make mathematics accessible to both girls and boys, girls interest and involvement rises.

Usefulness of Math Knowledge

A student's belief that mathematics has utility in her or his life (Fennema & Sherman, 1978) and the teacher's belief that students should be active participants in learning and doing mathematics are also important components in building an affinity to mathematics. For instance, in a related study of gender-related involvement with Lego TC logo, middle school girls' interest and involvement with Lego TC increased considerably when mixed gender groups were designed to give girls the key roles of key boarder and spokesperson (Cutler-Landsman, 1991). Initially, while girls were included as active learners in all groups, the projects students undertook did not seem relevant to girls and they quickly lost interest. However, when the structure was changed to truly integrate girls and boys into team projects and to provide girls with an opportunity to select projects, girls began to express considerable interest because they had the opportunity to share the boys' expertise in Legos (which they had come into the class with). The change in classroom structure to place girls in a position of relative power and importance as spokespersons enabled girls to both familiarize themselves with computer language and to develop the skills and confidence to "*explain the project and reflect on the problem solving strategies* [emphasis added] their group employed."

Mathematics Course Taking

While there is little difference in achievement in early grades, there is a significant difference in the number of advanced courses taken by males as opposed to females. If girls are clustered in lower level mathematics, their knowledge will be significantly less than males, particularly white males, who take advanced courses (Pallas & Alexander, 1983). The self-selecting out of mathematics in high school points to another message—one of sex role stereotyping—that mathematics is not for girls. Whether or not this is an overt message or part of the general socialization of females, by the time girls get to high school they “know” they do not belong in mathematics.

Thus, women are not present at the postsecondary level and in the work world of mathematics, science, or technology. By the time they reach college, most young women have opted out of mathematics- and technology-related programs, a process that begins to be most apparent after high school geometry. This phenomenon and its relationship to socialization can be seen in the enrollment in computer classes. While most computer activity is non-numeric, and computer use should not be perceived of as strictly a mathematics program, in most schools it is. And the limited enrollment of girls and young women reflects the distancing of females from mathematics. From elementary school through college, enrollment patterns consistently show fewer females than males using computers or participating in computer-related courses. In high schools, males outnumber females two to one in computer classes, while at the university level only 26.5 percent of master's degrees and 8.4 percent of doctorates in computer and information services were earned by women. And, in the work force, only 27 percent of all computer programmers and analysts are women (Lewis, 1985).

Social Expectations

Socialization

Research has shown that math anxiety and technophobia are learned responses—girls are not born hating mathematics (Fox, 1981). Such socialization begins at home. Females are socialized from the time they are very young to avoid risk taking—and in the culture of the United States mathematics or technology may be seen as risky business for females.

Within the home environment the treatment of male and female infants remains fairly stereotypic. For instance, girl babies are handled more delicately than are boys (Brauun & Linder, cited in Hensel, 1989). Even the toys given to boy and girl babies differ; from birth girl infants are discouraged from risk-taking, from exploring the world around them. Boys are given toys that encourage small motor skills and spatial visualization—necessary for later math success. Girls' toys often encourage relational or traditionally nurturing activities.

In child care settings, with infants and children between thirteen months and two years, research shows that child care providers respond to the children based on their own sex role beliefs, and they use the child's gender to guide their responses (Fagot, Hagan, Leinback, & Kronsberg, 1985). While there was no sex difference in the number of attempts infants made to communicate with the adults, the infant behaviors to which adults responded differed significantly. Adults were more likely to respond when girls used gestures or gentle touches or talked, and when boys forced attention through physical means or cried, whined, or screamed. When children are older and their behaviors more clearly defined, teachers apparently abandon the sex stereotype and begin to respond to the specific behavior of the child, but by this point the unconscious assignment of sex role stereotypes to the child is no longer necessary. For the most part, by the time they are three, children are performing well-rehearsed communicative activities that were developed before the child had an effective language system.

In another study that explored the dominant and submissive sex role behaviors in preschool children and their teachers, the patterns of male domination of conversation were emerging—a pattern modeled by the adults (Hendrick & Strange, 1989). The preschool teachers interrupted less when the boys were talking and they made no attempt to balance the larger number of male interruptions by encouraging girls to speak up or by recommending the boys allow the girls speaking time. As the researchers pointed out, these preschool girls were " . . . learning to know their place and what traditionally constitutes socially acceptable sex-role behavior . . . girls were learning to assume a less aggressive social role in conversation. It is quite possible since what they had to say was treated with less respect, they were also learning they were less important in the social scheme of things than were their male counterparts."

Family Expectations

Parent expectations of girls and boys differ significantly in terms of mathematics. This socialization process begins early and influences a girl's decision on whether or not to take specific math courses in high school. Researchers have found both that it is expectations that influence course taking and that parents are more willing to invest greater sums in their sons' education. Such often unconscious perceptions help perpetuate the assumption that girls cannot excel in mathematics.

Education Issues

Discourse

The socialization pattern of females continues in the school where the "hidden curriculum" that trains white males for public discourse and success is carried out, even if female math underachievement does not become manifest until high school. Whether it is a curriculum that fails to engage girls, unconscious behavior patterns and expectations, outright hostility to girls by teachers and male students, or the lack of encouragement from guidance counselors, the process of disengaging females from mathematics continues (Kramarae & Treichler, 1990). And, while numerous successful programs have been developed to change girls' attitudes toward mathematics, these programs often remain outside the traditional classroom. It needs to be seen whether these self-contained programs, such as those developed by Girls, Inc., can have the same results within the mainstream classroom.

The importance of what actually happens in classrooms, particularly in terms of teacher-student interactions and both teacher and student expectations, should not be underestimated. It is within the classroom that sex role expectations and socialization converge to influence both the curriculum and the real experiences of the students.

The discussion of discourse is at the heart of much of the discussion of mathematics today. The *Professional Standards for Teaching of Mathematics* (National Council of Teachers of Mathematics, 1991) focuses heavily on discourse, defined as the ways in which knowledge is constructed and exchanged in classrooms. The *Standards* discuss discourse in three sections, Teacher's Role in Discourse, Student's Role in Discourse, and Tools for Enhancing Discourse. Discourse is formed by both the teacher and the students and by the mathematics work they are doing. Through their role as teacher, adults send strong signals about the knowledge and the most valued ways of thinking and knowing. How this discourse is shaped has a significant impact on how students will construct mathematical knowledge.

The classroom remains a "chilly climate" for females (Sandler, 1982) long after initial interactions that send messages to female students that they are not welcome participants in education. But without explicit attention to the patterns of discourse in the classroom, the long-established norms of school are likely to dominate—competitiveness, an emphasis on right answers, the assumption that teachers have the answers, rejection of nonstandard ways of working or thinking, patterns reflective of gender and class biases (Ball, 1991). This cautionary note is of particular concern for girls, who have traditionally remained outside the standard discourse patterns of mathematics classes.

Providing girls with the opportunity and skills to be a public presence may be at the core of the longstanding difference in mathematics and science achievements between genders. If males are socialized for public speaking while females are socialized for private speaking (Tannen, 1990), then a classroom dynamic that addresses the issue of discourse along with mathematics content will be more successful for females.

A good reminder, then, is that " . . . girls may as a group be given less privileged access to certain kinds of learning experience. Secondly, classroom talk forms an important arena for the reproduction of gender inequalities in interactional power. In arriving at the second conclusion we can observe that the . . . ideal that schools exist to teach pupils how to take their —proper' position in the social order may still, at least in one respect, hold true" (Graddol & Graddol, 1986). Thus control of discourse within the classroom plays a significant role in teaching girls and boys their proper role within society. Until discourse is changed, females will still not achieve.

Curriculum Content and Orientation

The relationship between curriculum and discourse needs to be considered in any examination of mathematics achievement for girls. If girls are prevented from participating in the public discourse of the classroom, they will continue to excel only in that segment now seen as personal and relational—creative writing and composition—without developing the ability to debate and dialogue with peers. The systematic, although unconscious, exclusion of girls from group and class talk denies them an opportunity for successful and complete learning. Knowing they are excluded from the dialogue, girls may also develop alternative learning strategies that work well at the elementary levels but which put them at a disadvantage later (Claire & Redpath, 1989).

Too often education is constructed that removes learning from what is real and moves it to an arena of abstraction and argument (see Rich, 1979). In numerous mathematics classes students are pushed to "tear apart ideas," to debate theory, or to solve mathematics problems that seem totally disconnected from what is "real." This mainstream model of education, developed by and for males, may leave out the large percentage of students, including the female students in the class whose learning styles are neither acknowledged nor validated in education. If the education model is a male model where knowledge is achieved through public debate and argument (Ong, 1981), the classroom discourse style that focuses on challenging one another is at odds with the conversational style of many women—where ideas build on one another and the focus is on group consensus. As a respondent in the landmark book *Women's Ways of Knowing* (Belenky, Vicker-Clinchy, Goldberger & Tarule, 1986) explained, “It's not a battle between the gods that concerns women. Women are concerned with how you get through life . . . What each little teeny tiny incident—how it can affect everything else you do.”

Ironically, it is this perception of connection, of paying attention to the little things, that may be at the heart of much scientific or mathematical discovery—it is intuition and creativity, together with a grounding in inquiry, that guides real mathematics, as opposed to arithmetic. Unfortunately, much of what passes for mathematics education today is devoid of the “little teeny” incidents that show the connections. The language of discovery and invention is not always the language of abstraction: that comes later, after the creative process has occurred.

If, as Gilligan (1982), Belenky et al. (1986), and others have suggested, females most commonly utilize a “connectivist” mode of thinking, the traditional mode of mathematics education—with its level of abstraction from human context—is both alien and alienating. Borasi's (1991) research revealed that the image of mathematics as a cold, cut-and-dried, impersonal discipline is often at the bottom of women's dislike of the discipline, and consequently, of their decision to abandon mathematics quickly.

Research may also point to disparities in the math curriculum itself that reinforce the perceptions that girls are not mathematical. If, as Selma Greenberg has postulated, early elementary math curriculum focuses on those interactive, memorization skills that girls come prepared with, only to shift later to the higher order, abstract concepts that depend on spatial visualization (boy's skills), then the dynamic of the discourse plays an unusual role. While girls are achieving in early elementary school, they are utilizing skills they arrived with and the discourse focused on “remediation” for boys, helping them to develop these initial skills. When the curriculum shifts, however, there is no parallel discourse shift to include girls in the development of their higher order math skills. Boys have a grounding in this discourse and so it often continues on without the involvement of girls, an uninvolvement that remains unnoticed by teachers and students themselves.

Teacher Attitudes and Behaviors

Unconscious Signals

Hendrick and Strange (1989) found that when role assigning was done at the conscious level, the teachers did not favor either sex. Their awareness of the detrimental effects of sex role stereotyping in some areas enabled them to change their own behaviors to foster less stereotyped roles and expectations. However, at the unconscious level, teachers were unaware of the more subtle aspects of their behavior that involved how they used language. They, as well as other members of the children's adult world, were unconsciously passing on a set of behavior expectations that would, as the girls grew older, get in the way of their academic achievement (Sadker & Sadker, 1985; Rosenthal & Jacobsen, 1968).

These expectations are affected by the race, class, and gender of the student. Here, Delpit's work (1988) can be instrumental in understanding and addressing the issue of discourse and power when she asserts that students must be *taught* the codes needed to participate fully in the mainstream of American life, that they must be allowed the resource of the teacher's expert knowledge, while being helped to acknowledge their own “expertness” as well; and that even while students are assisted in learning the culture of power, they must also be helped to learn about the arbitrariness of those codes and about the power relationships they represent. Currently, white males receive the most positive attention within a class; they are also pushed to think, to expand ideas, to defend their positions. In other words, they are being prepared to succeed in the world of public discourse; the classroom discourse is preparation for adulthood. On the other hand, African American students receive more negative feedback for behavior, and more positive-negative feedback (comments that began as positives but include a negative modifier, thus sending mixed messages). Females receive less praise, less negative behavior feedback, less neutral procedure feedback, and less nonacademic feedback. White females receive less total communication feedback than all other groups (Irvine, 1985). As the invisible members of the classroom, females have a different educational experience from males. This invisibility, coupled with different sex role stereotyped discourse patterns, effectively prevents females from participating equitably in the classroom discourse. And, if students are not taught to analyze this dynamic, they will assume it is normal and continue to respond to it.

Irvine (1985) points to considerable research that indicates the patterns of sex role stereotypes are so ingrained as to remain invisible. Teachers see girls as objects of attachment rather than of concern; they perceive girls more favorably—because they are not attracting attention, acting out, or otherwise participating in the activity of the classroom. As in the preschool setting, teachers initiate more contact with boys, and boys are more likely to call out answers. While girls are less likely to call out answers, teachers also respond significantly less to their attempts to initiate conversation. In this pattern of control of discourse, it is not even necessary for males to have the right answers, but rather to get noticed and engage with the teacher. Sadker and Sadker (1985) indicated that at all grade levels and in all subjects, females have fewer opportunities to interact. Unfortunately they also found the educators were unaware of the impact of this pattern of bias.

Many teachers feel they are treating their students fairly. Spender, in her book *Invisible Women: The School Scandal* (1982), quoted a teacher who discovered she spent only one-third of her time interacting with the girls, "But I thought I spent more time with the girls." Her surprise was reinforced by comments from the boys in her class who complained she spent all her time with the girls. Spender and researchers Sadker and Sadker show that teachers continue to focus their attention on male students. However, there seems to be a maximum level of involvement, beyond which boys and their teachers unconsciously feel girls should not participate. While the perception may be that girls are participating in the discourse, they in fact are not. The implications of an assumption that girls are not entitled to equal participation in discourse are enormous. Although they may be well prepared for written work, girls at the elementary level are already prepared not to participate in the larger public discourse necessary for success as adults.

Differential Attention

Since the role of questions and wait time have been discussed as important in the construction of discourse, Leder's (1987) research on teacher engagement with sixth grade mathematics students is instructive. Prior research has shown that teachers give the most attention to students perceived of as above average. In mathematics, this correlation has born out significantly; those students the teacher perceives of as above average perform better on tests. However, by examining the level of interaction and quality of engagement in relation to gender, a significant pattern begins to emerge. Girls were given considerably more teacher engagement time and attention for product questions in mathematics, while boys received significantly more engagement and attention on process (or higher order) questions. This unconscious discourse mode reinforces girls' sense of disengagement from mathematics and removes them from the construction of higher level cognition skills needed for progressing in mathematics. Over a number of years, this dynamic could contribute to the differences between males and females on achievement tests and explain somewhat the difficulty of improving girls' performance on higher level tasks (see Peterson & Fennema, 1985, and Johnson, 1985, cited in Leder, 1987).

This lack of engagement with the teacher in mathematics is reinforced in other research (Brophy & Good, 1974) showing that teachers interacted more with high achieving boys than with high achieving girls, that teachers initiated more contacts with boys, and that teachers accepted wrong or poor answers more often from boys. Like Tannen's findings of public/private discourse differences, the boys in math classes initiated more public contacts with the teachers, while girls initiated more private contacts. Similarly, Reyes (1981) found that teacher mathematics interactions with boys were considerably greater than they were with girls. Reyes found that a considerable number of girls had no interactions at all with their teacher in certain mathematics classes. As Leder (1987) points out, “The differences in interaction patterns . . . are likely to result in both affective and achievement related attendant differences.” Boys, therefore, as the focus of the discourse are more likely to develop a strong task intrinsic motivation (typical of high achieving students) while girls are more likely to develop a less functional behavior of working for teacher approval.

Classroom Organization and Teaching Methods

Student Participation

Classroom dynamics depend on everyone's awareness of the rules—however unconsciously. These rules, called participation structures, are the typical arrangements of speakers and listeners with associated rules for participation (Philips, 1972). The participation structure must be understood by all speakers or miscommunication results. This is particularly evident when working in cross-cultural classrooms where one discourse style might be perceived as an embarrassing intrusion by a student from another culture (Carlsen, 1991). Less evident is the miscommunication and tension that results when the discourse style is one that excludes female participation. But this topic is now receiving considerable attention due in part to the release of the recent research report by the American Association of University Women (AAUW, 1992), *How Schools Shortchange Girls*.

This report, which focused national attention on the disparity of educational experiences between boys and girls, examined all aspects of education, ranging from sex role stereotypes in early childhood to the discourse dynamics of the university. One critical component of this examination focused on classroom interactions—both teacher-student and student-student. From preschool to the university, the study found, males receive more teacher attention than do females, and, not only do males demand more attention, but teachers of both sexes solicit their responses. This is particularly true with science and mathematics classes (AAUW, 1992).

The report also highlights the often overlooked student-student interaction patterns that also contain gender stereotyped discourse dynamics. In the classroom, boys simply do not treat girls well. Not only do boys wield power in discourse, but they use sexual harassment as a means to assert their power and to silence girls. Sexual harassment in both middle and high schools is increasing, and rather than seeing this as serious misconduct (and prohibited by Title IX), many school authorities often treat sexual harassment as a joke. This sexual harassment also extends to sexual orientation or sexual preference, yet is consistently ignored (AAUW, 1992). The power dynamic in which schools ignore sexist, racist, homophobic, or violent interactions both implies tacit approval of such behaviors and sends a clear message to girls that the classroom is not a place for them.

A study comparing communication patterns within private preschools and Head Start programs showed that teachers of lower economic status children spent more time interacting with adults rather than with children, compared to classrooms for middle income children. Lower SES children had fewer opportunities for verbal communication with their teachers, and thus fewer opportunities to learn how to have sustained interactions with others, particularly teachers. Poorer children, then, have fewer opportunities to learn the codes of discourse that will help them participate in school (Quay & Jarrett, 1986). For girls, this plays a critical role in terms of classroom discourse; poor girls are even less likely to be able to be active participants in the classroom discourse. This is borne out in the research that shows that girls from lower economic backgrounds tend to drop out of mathematics earlier than girls from middle class backgrounds.

These sex role stereotyped communication patterns continue to be reinforced on the unconscious level in elementary school. Two similar studies (French & French, 1984; Claire & Redpath, 1989) analyzed classroom discussions of children between the ages of 9 to 11. Despite different classroom settings, boys took three times as many turns speaking. By the time students reach college, men totally dominated the conversation, in some classes speaking as much as 12 times longer than women (Krupnick, 1985).

Just as Coates (1988) and Krupnick (1985) found in their studies of adult conversation, Redpath observed that while still in elementary school, boys were using interruptions to gain control of the conversation. Girls, on the other hand, used interruptions "to help and support the girl who was speaking with useful information . . . so that the speaker did not . . . fall silent."

Instructional Style

For many educators, the impact of a prior unconscious socialization pattern that literally prevents girls from being participants in their own education is often overlooked, as are its implications for the classroom. Linguistics researcher Deborah Tannen (1991) cited a comment from a colleague that he had always taken for granted that the best way to deal with students' comments was to challenge them. "This, he felt was self evident, sharpens their minds and helps them develop debating skills. But he had noticed that *women were relatively silent* in his classes" (emphasis added). When he switched to discussion with relatively open-ended questions and letting comments go unchallenged, he noticed more women were participating.

Research indicates that individuals adjust their verbal and nonverbal patterns to mirror the behavior of others they like, whom they wish to like them, or whom they see as having the power to reward them. In the case of students, the teacher maintains a great deal of power; additionally, girls who are often dealing with issues of self-esteem also adopt behaviors that will "make the boys like them." Thus, within the classroom, girls often assume a traditional sex role stereotyped conversation pattern they do not use in single sex settings. A 1977 study by McMillan found that in small groups women produced more modal constructions, tag questions, and imperatives in question form when men were present than when they were not.

The very language of the mathematics discourse plays into sex role socialization. As Damarian (1990) points out, for many centuries mathematics was the arena of men, and the language reflects that with its references to aggressiveness—mastery, power, hierarchies of objectives. This language of aggression, coupled with the emphasis on abstract activities that characterize much of current math instruction may silence females within the mathematics discourse. Like Gilligan (1982) and Belenky et al. (1986), Damarian points to the need for the sense of connection in order for females to feel involved in this education:

> Women learn abstractions (such as mathematical principles) best if statements of rules are preceded by quiet observation, by listening to others, and by personal experiences that women can relate to the abstractions. (1990)

By exploring the socialization of discourse for males and females, the pattern of discourse in mathematics classes takes on a new light. If the accepted mode of discourse is a questioning/challenging model that highlights individualism and competition, where do girls socialized to a more collaborative, passive mode fit in? A critical question that needs to be examined is what happens when girls are challenged within a mathematics classroom. If they have not developed a level of process skills that enables them to be comfortable with their own math abilities, the challenge from the teacher to explain a process or to take the lead—which might be seen by males as a positive motivator—may in fact put a girl on the spot, and may have the opposite effect of motivating her to excel.

Despite the obstacles, since the classroom remains the training ground for public discourse (the workplace, politics, meetings) for adults, girls must develop a comfort with and skill in public debate/discussion and with individual leadership even should they choose another model as their primary discourse mode. As women within a public arena, they must understand the rules and be able to participate even as they change the rules. The trick, then, may be to find ways to restructure the discourse model to include different forms of communication, including traditional debate. This new form of discourse is consistent with the mathematics reform agenda, and may in fact, evolve into a different kind of mathematics language.

Conclusions and Recommendations

The Context of Mathematics Education

Mathematics education takes place within the context of culture, both the school culture and a larger culture. Norms, values, and beliefs that form attitudes and behaviors are fundamental to these cultures. Through their impact on the contexts of mathematics education, they help determine not only the nature of the education, but whether there is equitable access to learning. Further, since individuals interact with the culture—accepting, mediating, or resisting certain cultural messages—it is important to explore "resistance" (Giroux, 1983; Bell, 1989) among students and teachers to the dominant perceptions of gender-related expectations within mathematics. Placing mathematics education within the context of culture allows it to be seen as a dynamic process to be continuously shaped by the individuals within the culture. With a broader understanding of this cultural context—its norms, values, beliefs, and stereotypes—educators can begin to consciously change the culture to better respond to the education of girls.

The challenge to educators is complex: to encourage girls and women to participate in mathematics, and to change the paradigm of discourse that prevents their participation. Fennema and Peterson (1985) have suggested that teachers need to directly encourage autonomous learning behaviors in girls. They suggest that teachers should engage girls in high-level discourse interactions, provide praise and positive feedback for effort and for appropriate strategies, develop strategies for encouraging divergent thinking, and encourage independence. These appropriate strategies need to be explored within the context of the classroom, the socialization of discourse, and what is known about the process of structural change. Otherwise, girls will continue to be seen as the problem, rather than as participants in a complex system of unconscious exclusion that begins at birth. There are, however, numerous ways for educators and parents to begin to change personal and structural barriers to math achievement for girls. As Campbell has stated, "We know what works, it's time to do it."

New Discourse Strategies

There is an extensive body of research and practical applications that can be useful in the exploration of ways to change mathematics education discourse patterns to include females. For instance, new education models, particularly cooperative learning, can create a different, more equitable, dynamic within the classroom. The Lego action research model, described earlier, comprises a cooperative learning setting where boys and girls need to draw on one another's strengths; the traditional concept of who gets to control the discourse is eliminated. By providing opportunities for girls to become leaders, the teacher builds a comfort level with computer technology and with being an equal partner in the discussion. The modeling that occurs in this setting can significantly change perceptions of both boys and girls on the control of discourse in mathematics and other classes; this perception, if reinforced, will carry with the students as they move into upper grades.

Critical to a paradigm shift is the involvement of the teacher. All the teachers in the studies discussed above were unaware of the gender-related differences within the classroom. When sensitized to this issue, they can and will begin to change their methods, provided they too are given the safety, time, and support to do so. Not only does this call for considerable resources for inservice and preservice training for teachers around the issues of gender equity and the impact of discourse on their classrooms, it also makes a case for the role of teacher as action researcher. Within a classroom model where teachers are able to examine and reflect on their teaching, try out new approaches, and further refine their facilitation, rather than control, of the discourse, females, as well as those males currently excluded from the discourse, can make significant progress.

Recommendations

The following suggestions, gathered from the research, can help create an equitable environment that encourages the mathematics development of both females and males.

1. ***Examine our own attitudes.*** Do we believe females are not as skilled in mathematics and do we play that out in our interactions? Do we allow male students to control the discourse? Do we interact with male students more than with the female students? Do we discourage risk taking and autonomous behavior in girls? Do we use challenges as a major motivator rather than examine ways to change the discourse, for instance, by asking open ended questions, not making immediate judgments on responses, or involving girls collectively in discussions?

2. ***Start early to prevent sex role stereotyping.*** Parents can foster the ability to take risks, to be entranced by mathematics. Encourage females as well as males to explore their environment; help young girls take risks; introduce both girls and boys to action toys and team sports to increase their spatial visualization skills; and provide examples of women and men working in mathematics, technology, and the sciences. Assert how both boys and girls can do this work and be ready to counter the denials from children—they've already heard the other message.
3. ***Assign classroom and household chores to children equitably.***
4. ***Watch the words we use.*** Children as well as adults do not translate the word "man" to mean both "man" and "woman." Nonsexist language is critical to the change in discourse, as is a shift from the language of aggression (kick, take a stab at, rip it apart).
5. ***Devise comfortable ways for girls and boys to play together in a variety of active and quiet play.*** This breaks down the stereotyped behaviors that get reinforced later and opens the way for ongoing honest communication.
6. ***Emphasize nonstereotyped roles in creating and using mathematics word problems.***
7. ***Teach mathematics to young children through play, using situations that introduce girls and boys to a variety of career options early.*** As Campbell's research shows, girls often do not even think about advancing in mathematics because they have no idea of how they could use it in their adult life. Providing career examples early helps students expand their dreams.
8. ***Include activities that involve all students as active participants and that include spatial visualization skills and hypothesizing.*** Encourage students to share their learning and ideas through oral presentations, discussions or writing reports, journals or logs. Create a class journal in which student reports are reviewed by classmates.
9. ***Encourage girls and young women to participate in extracurricular math or science activities.*** There, they can make friends with other girls who are interested in and like math. Provide female role models who are articulate, successful, and happy with their work as mathematicians, scientists, technology specialists.
10. ***Involve students as active learners and involve them in many hands-on activities.***

11. ***Discover any academic deficiencies girls may have and correct them in ways that encourage them to continue in mathematics.*** For example, additional one-on-one work or cooperative learning sessions that incorporate support for becoming autonomous will have a positive effect, as opposed to the negative effect of being singled out as being deficient.
12. ***Make mathematics fun.*** Listen carefully to girls and examine existing educational materials to find opportunities to let girls have fun with math—the concept of decreasing stress to increase the transmission of knowledge is vital to any shift in paradigm.
13. ***Create a mathematics environment that supports student inquiry through the use of real life situations,*** such as those found in the media, concerns about social issues, or even how international math achievements are developed. These activities should include opportunities to be "messy"—to discover there are uncertainties and limits within mathematics inquiry.
14. ***Provide additional readings or external experiences as additional resources*** in ways that encourage students particularly girls, to become independent thinkers. Often, simply providing girls with the next day's assignment prior to discussion in class may help them to better understand the material and engage in the discussions.
15. ***Encourage students to become reflective about their work,*** making connections with other learning activities or knowledge gained outside the math classroom.

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