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ABSTRACT

Research has provided rich documentation of knowledge on variables that are related to gender and mathematics. Moderate change in what has happened with females in mathematics education has occurred partly because of this scholarship. This paper discusses the research on mathematics and gender and the need to continue research that documents the status of gender differences as they exist. It focuses on gender differences in mathematics. It also states that research must be supplemented with new types of scholarship focused on new questions and carried out with new methodologies which will help in the identification of important emphases for further new research, which will also ensure that women's voices will become a major part of all educational scholarship. Cognitive science and feminist perspectives in this issue are considered. (Contains 47 references.) (ASK)

Gender Equity for Mathematics and Science

Invited Faculty Presentation

Elizabeth Fennema

Contents

My own value positions influence strongly what I am going to say. This is nothing new. My entire professional career has been predicated on the belief that women deserve equity with men in all walks of life, and that belief has informed a significant part of my scholarly activities, particularly in the area of gender and mathematics. I have always believed that I can learn how to better facilitate the learning of mathematics by females through research.

I also believe that there are routes other than research for gaining knowledge about how to help females achieve equity. Many others have studied gender and mathematics and/or developed interventions designed to assist females in learning mathematics. Their work has greatly enriched my work and I am indebted to them. However, this paper is focused on what I know best, that portion of my professional work concerned with mathematics and gender.

Research, Mathematics, and Gender

In 1974, my first article about gender was published in the *Journal of Research in Mathematics Education* (Fennema, 1974). In this article, which was a review of extant work that had been done on sex differences in mathematics, I concluded that, while many articles had been poorly analyzed and/or included sexist interpretations, there was evidence to support the idea that there were differences between girls' and boys' learning of mathematics, particularly in items that required complex reasoning; that the differences increased at about the onset of adolescence; and that these differences were recognized by many leading mathematics educators. As an aside, it was really the writing of that 1974 article that turned me into an active feminist, compelling me to recognize the bias that existed toward females, which was exemplified by the recognition and acceptance by the mathematics education community at large of gender differences in mathematics as legitimate.

The Fennema-Sherman studies (Fennema & Sherman, 1977; 1978; Sherman & Fennema, 1977), sponsored by the National Science Foundation and published in the mid-1970s, documented sex-related differences in achievement and participation in Grades 6-12. Although there were many subtle results, these results basically agreed with those of my original review with respect to gender differences in learning. In addition, Sherman and I found differences in the election of advanced level mathematics courses by males and females. When we coupled the achievement differences with the differential course enrollment, we hypothesized that if we could encourage females to participate in advanced mathematics classes at the same rate that males did, gender differences would disappear. Many things are learned as one does research, and from the stating of this hypothesis I learned that what you write and say can stay with you a long time. This hypothesis, labeled as the differential course-taking-hypothesis, became a point of attack by Julian Stanley and Camilla Benbow (Stanley & Benbow, 1980), who used their interpretations of some of their studies as a refutation of our hypothesis. They then used their work as evidence that gender differences in mathematics are genetic. Although widely attacked and disproved, the publication of their claims in the public media did have unfortunate repercussions (Jacobs & Eccles, 1985).

Affective or attitudinal variables were also examined in the Fennema-Sherman studies. Identified as critical were beliefs about Usefulness of mathematics and Confidence in learning mathematics, with males providing evidence that they were more confident about learning mathematics than were females, and males believing that mathematics was and would be more useful to them than did females. It also became clear that, while young men did not strongly stereotype mathematics as a male domain, they did believe much more strongly than did young women that mathematics was more appropriate for males than for females. The importance of these variables, their long-term influence, and their differential impact on females and males was reconfirmed in many of our later studies, as well as by the work of many others (Leder, 1992).

One cognitive variable also studied in the Fennema-Sherman studies was spatial skills or spatial visualization, which I continued to investigate in a three-year longitudinal study in collaboration with Lindsay Tartre (Fennema & Tartre, 1985). Differences between females and males in spatial skills, particularly spatial visualization or the ability to visualize movements of geometric figures in one's mind, have long been reported (Maccoby & Jacklin, 1974). Since items that measure spatial visualization are so logically related to mathematics, it has always appeared reasonable to believe that spatial skills contributed to gender differences in mathematics. We found that, while spatial visualization is positively correlated with mathematics achievement (which does not indicate causation), not all girls are handicapped by inadequate spatial skills, but perhaps only those girls who score very low on spatial skills tests.

The Fennema-Sherman studies have had a major impact, although they were not particularly innovative, nor did they offer insights that others were not suggesting. However, they were published in highly accessible journals just when the concern with gender and mathematics was growing internationally. Partly because the studies were accessible and not generally controversial and because they employed fairly traditional methodology, their findings have been accepted by the community at large, and many have used them as guidelines for planning interventions and other research. The studies have been identified by two independent groups (Walberg & Haertel, 1992; Anon., in progress) as among the most quoted social science and educational research studies during the last two decades. Each week, I still receive at least one request for information about the Fennema-Sherman Mathematics Attitude Scales, which were developed for those studies. The research reported in these studies, in conjunction with the research of others, has had a major impact. The problems of gender and mathematics were defined and documented in terms of the study of advanced mathematics courses, the learning of mathematics, and certain related variables that appeared relevant both to students' election of courses and learning of mathematics.

After completing the Fennema-Sherman studies, with the indispensable aid of many others (Laurie Reyes Hart, Peter Kloosterman, Mary Koehler, Margaret Meyer, Penelope Peterson, and Lindsay Tartre), I broadened my area of investigation to include other educational variables, particularly teachers, classrooms, and classroom organizations. We studied teacher-student interactions, teacher and student behaviors, and characteristics of classrooms and teaching behaviors which had been believed to facilitate females' learning of mathematics.

The series of studies dealing with educational variables, reported and summarized in the book Gilah Leder and I edited (Fennema & Leder, 1990), suggested that it is relatively easy to identify differential teacher interactions with girls and boys; in particular, teachers interact more with boys than with girls, praise and scold boys more than girls, and call on boys more than girls. However, the impact of this differential treatment is unclear and difficult to ascertain. The data that resulted from the studies do not support the premise that differential teacher treatment of boys and girls causes gender differences in mathematics. This conclusion has also been reached by others (Koehler, 1990; Leder, 1982; Eccles & Bluemenfeld, 1985). In 1993, there still is not sufficient evidence to allow us to conclude that interacting more or differently with girls and boys is a major contributor to the development of gender differences in mathematics.

Many intervention programs have been designed to help teachers recognize how they treat boys and girls differently. Unfortunately, such programs do not appear to have been successful in achieving the elimination of gender differences in mathematics. I believe that differential teacher treatment of boys and girls is merely a symptom of many other causes of gender differences in mathematics and that, as in medical practice, treating the symptom is not sufficient to change the underlying cause.

Identifying behaviors in classrooms that influence gender differences in learning and patterns in how students elect to study mathematics has been difficult. Factors that many believed to be self-evident have not been shown to be particularly important. Consider sexist behaviors, such as those indicating that mathematics is more important for boys than for girls. No one would deny that such behaviors exist. However, Peterson and I (Peterson & Fennema, 1985; Fennema & Peterson, 1986) did not find major examples of overall sexist behaviors on the part of teachers, but rather small differences in teacher behavior, which, when combined with the organization of instruction, made up a pattern of classroom organization that appeared to favor males. We also found patterns of teacher behavior and classroom organization that influenced boys and girls differently. For example, competitive activities encouraged boys' learning and had a negative influence on girls' learning, while the opposite was true with cooperative learning. Since competitive activities were much more prevalent than cooperative activities, it appeared that classrooms we studied were more often favorable to boys' learning than to girls' learning.

In connection with this series of studies, Peterson and I proposed the Autonomous Learning Behaviors model, which suggested that, because of societal influences (of which teachers and classrooms were main components) and personal belief systems (lowered confidence, attributional style, belief in usefulness), females do not participate in learning activities that enable them to become independent learners of mathematics (Fennema & Peterson, 1985). This model still appears valid, although my understanding of what independence is has grown and I believe that independence in mathematical thinking may be learned through working in cooperation to solve mathematical problems.

Intervention Studies

By about 1980, there were some rather consistent findings from research on gender and mathematics. We knew that in the United States, when studying mathematics became optional in the secondary schools, fewer females than males were electing to study mathematics; young women did not believe that mathematics was particularly useful and tended to have less confidence in themselves as learners of mathematics. We had strong evidence that boys stereotyped mathematics as a male domain and we had identified many societal influences that suggested that mathematics learning was not particularly appropriate for girls. Based on these research findings, with the help of three others (Joan Daniels Pedro, Patricia Wolleat, and Ann Becker DeVaney), I developed an intervention program called Multiplying Options and Subtracting Bias (Fennema, Wolleat, Becker, & Pedro, 1980). This approximately one-hour, school-based program, composed of video tapes and a workshop guide, was extensively evaluated, particularly with regard to its effectiveness in increasing females' participation in advanced secondary school mathematics classes and its impact on confidence and perceived usefulness. We reported that this short intervention, which helped girls and boys recognize the importance of mathematics and the stereotyping of mathematics that was prevalent, resulted in more girls, and more boys, electing to take mathematics courses. A more negative finding, however, was that pointing out the sexism that exists in classrooms and their environment increased the girls' anxiety about mathematics.

Another educational finding, which has not been systematically studied by me, or anyone else that I know of, is the variation in gender differences in mathematics across schools and across teachers. Casserly (1980) reported that some schools were much more successful in attracting females to the most advanced mathematics classes than were other schools. The Fennema-Sherman studies reported variations in the size of the differences between schools. And one large urban school system in the U.S. reported substantial discrepancies in gender difference scores by high schools on the SAT, a college entrance examination that is recognized as being a good test of mathematical reasoning (Personal Communication, 1985). Confirming this variation between schools and teachers, recent unpublished work of mine has identified certain teachers whose classes consistently show greater gender differences in favor of males than do the classes of other teachers.

My next set of studies was conducted with Janet Hyde. For these studies, we did a series of meta-analyses of extant work on gender differences reported in the U.S., Australia, and Canada (Hyde, Fennema, Lamon, 1990; Hyde, Fennema, Ryan, & Frost, 1990). The results indicated that, while gender differences in mathematics achievement might be decreasing, they still existed in tasks that required functioning at high cognitive levels. It also seemed that the more nearly tests measured problem solving of the most complex cognitive level, the more tendency there was to find gender differences in mathematics in favor of males. The international assessment reported by Gila Hanna (Hanna, 1989) reported results that basically confirmed this.

My work has not been the sole chain of inquiry that has occurred during the last two decades. The work of Jacquelynne Eccles, Gilah Leder, and others (Leder, 1992) has been conducted independently and closely paralleled the major themes I addressed. An overly simplistic and not inclusive summary suggests that during this time scholars documented that differential achievement and participation of females and males existed; next, some related educational and psychological variables were identified; explanatory models were then proposed; and finally (or concurrently in some cases) interventions, based on the identified variables, were designed to alleviate the documented differences.

One line of inquiry that I have not pursued, but which has added a significant dimension and more complexity to the study of gender and mathematics, is the work that has divided the universe of females into smaller groups. In particular, the work of the High School and Beyond Project (a large multiyear project that documented gender differences in mathematics as well as many other areas) as interpreted by Secada (1992), and the work of Reyes (Hart) and Stanic (1988) has investigated how socio-economic status and ethnicity interact with gender to influence mathematics learning. The U.S., as well as many other countries, is a highly heterogenous society, made up of many layers, divisions, and cultures. The pattern of female differences in mathematics varies across these layers and must be considered.

For a number of years, because I was asked so often to speak about gender and mathematics, I compiled a list of what I had concluded research, my own and others, had shown. Following is a portion of the list I made in 1990.

Gender Differences in Mathematics 1990

1. Gender differences in mathematics may be decreasing.
2. Gender differences in mathematics still exist in:
    - Learning of complex mathematics
    - Personal beliefs in mathematics
    - Choice that involves mathematics
3. Gender differences in mathematics vary by:
    - Socioeconomic status and Ethnicity
    - School
    - Teacher
4. Teachers tend to structure their classrooms to favor male learning.
5. Interventions can achieve equity in mathematics.

On the basis of an examination of the five items on this list that still reflect my thinking, it is clear that, in the two decades following my original review in 1974, my understanding of gender and mathematics has grown as far as related variables are concerned, but the same gender differences, albeit perhaps smaller, still exist. I now can describe the problem more precisely. I know that large variations between groups of females exist; I know that there are differences among schools and teachers with respect to gender and mathematics issues; I know that females and males differ with respect to personal beliefs about mathematics; and I know that intervention can make a difference. I understand that the issue of gender and mathematics is extremely complex. And I accept without question the basic premise of the International Commission on Mathematical Instruction Study Conference on Gender and Mathematics (1992) - i.e., that "there is no physical or intellectual barrier to the participation of women in mathematics." But in spite of all the work done by many dedicated educators, mathematicians, and others, the "problem" still exists in much the same form that it did in 1974.

Now before I sound too pessimistic, it should be noted that there are many females who are achieving in mathematics and are pursuing mathematics-related careers. However, let me reiterate that in spite of some indications that achievement differences are becoming smaller, and they were never very large anyway, they still exist in those areas involving the most complex mathematical tasks, particularly as students progress to middle and secondary schools. There are also major differences in participation in mathematics-related careers. Many women, capable of learning the mathematics required, choose to limit their options by not learning mathematics. And while I have no direct data, I strongly suspect that the learning and participation of many women, who might be in the lower two thirds of the achievement distribution, have not progressed at all. I must conclude that many of the differences that were reported in the 1970s, while smaller overall than they were then, still exist in 1993.

New Scholarship on Gender and Mathematics

Much of what we know about gender and mathematics has been derived from scholarship that has been conducted using a traditional social science research perspective - i.e., a positivist approach that has looked basically at overt behaviors such as answers on a mathematics test, the amount one agrees with an item that is part of a Confidence scale, interactions between a teacher and a student, or the career decisions that students make. Usually, in positivist educational research, studies are done by a researcher who decides which overt behaviors are important to study, figuring out a way to count or measure the behaviors, and then studying the counts in some way. Often groups are studied - e.g., all females, all black females, or all females who study physics at a university. Measures of central tendencies (averages) and variability between groups are compared, or relationships between the variables are examined. The purpose is usually to describe the groups with respect to a behavior, examine relationships between behaviors, or to use the results that are found to predict the behavior of others. For example, when the Fennema-Sherman studies reported differential achievement, it was based on comparing the mean responses and standard deviations on a standardized achievement test by a well defined group of females with the mean responses and standard deviations of a group of similar males. Certain findings of differences were identified as statistically significant, which can be interpreted as meaning that the findings did not occur by chance but probably existed in the universe of similar males and females in the same proportion as in the population studied.

Studies conducted from a positivist perspective have provided powerful and rich information about gender and mathematics. However, an understanding of gender and mathematics based on studies done from this perspective is limited. Perhaps it is evidence of narrow vision, but I do not believe that we shall understand gender and mathematics until scholarly efforts conducted in a positivist framework are complemented with scholarly efforts that use other perspectives. Many educational researchers are using new perspectives and their work is beginning to provide important insights into teaching, learning, and schooling. I believe that research conducted within these new perspectives would also provide important insights into the issues involving gender and mathematics.

Although there are many directions that scholarship on gender and mathematics could take, I would like to discuss and provide examples of research from two perspectives: cognitive science perspectives, which emphasize the irrelevance of female-male differences, and feminist perspectives, which emphasize that female-male differences are critical to the learning of mathematics.

Cognitive Science Perspective

Brown and Borko (1992) define cognitive psychology as "the scientific study of mental events, primarily concerned with the contents of the human mind (knowledge, beliefs) and mental processes in which people engage." Central to this perspective is the idea that much of behavior is guided by mental activity or cognitions. Since it is difficult to get at mental processes, data collection techniques and interpretation are very different from that used in positivist research. Usually the sample size is small and individual interviews provide much of the data. In most such research related to schooling, researchers request that the subject report about his/her mental processes, either asking subjects to think aloud during problem solving, or stimulating recall where subjects might view a video tape of their actions as they are asked to report what they were thinking. Researchers examine the personal reports and look for universals that apply to all people. Much of the current research in the mainstream of mathematics education is being conducted using a cognitive science perspective. Many studies of teachers' knowledge and beliefs, as well as most of the work on learners' thinking within specific mathematical domains, are examples of this approach.

Consider one of the more robust lines of inquiry in mathematics education, the work on addition and subtraction done with young children (Carpenter, Moser, & Romberg, 1982). Addition and subtraction were defined precisely as semantically different word problems that can be solved with addition/subtraction; children were asked in individual interviews to solve the problems; and the interviewer probed, either during or following problem solution, until s/he understood how the problems were solved. The researchers looked for and identified patterns of problem-solving behavior that seemed to reflect the mental activities of the children.

Out of this work, universals were identified with respect to how young children, both females and males, come to understand basic arithmetic ideas. Counting and modeling solution strategies, which are developed intuitively in order to make sense of one's environment, were among those universals. These universals are found in many cultures - both in those cultures where schooling is at a minimum and in highly schooled societies (Adetula, 1989; Olivier, Murray, & Human, 1990; Secada, 1991). These modeling and counting strategies provide the foundation for the child's development of more sophisticated understanding.

While most researchers working within this paradigm have not specifically investigated gender differences, for the last ten years Tom Carpenter and I have examined gender differences as we investigated the application to instruction of the universals identified by the work in addition and subtraction (Carpenter and Fennema, 1992). We have noted some differences in maturity between young girls and boys with respect to problem solving, but no differences in how boys and girls solve arithmetic problems. Thus, at our present level of knowledge, we believe that the processes used by females and males to make sense of arithmetic are essentially the same. And, when such findings are used by expert teachers, gender differences in mathematics appear to be irrelevant. Because such teachers can understand each individual's mental processing, instructional decisions do not appear to be influenced by teachers' beliefs related to gender. They teach to the cognitive level of their students and are not affected by superfluous issues.

Cognitive science research has also provided insights into teachers' behaviors, knowledge, and beliefs, although little has been done related to teachers' cognitions about gender. Such studies may lead to deeper understanding of gender differences in mathematics as understanding is gained about the mental life of students, teachers, and others, and how it influences daily decisions about learning mathematics. Unfortunately, there are not many studies related to gender that have been done using this perspective. Once again, I turn to my own and my colleagues' work. Our last study on gender and mathematics concerned teachers' knowledge of and beliefs about boys' and girls' successes in mathematics (Fennema, Peterson, Carpenter, & Lubinski, 1990). Although teachers thought the attributes of girls and boys who succeeded in mathematics were basically similar, teachers' knowledge about which boys were successful was more accurate than teachers' knowledge about which girls were successful; and teachers attributed the boys' successes more to ability and girls' successes more to effort. Linda Weisbeck's (1992) results add some interesting dimensions to our knowledge of teachers' cognitions. During stimulated recall interviews, teachers reported that they thought more about boys than about girls during instruction. However, the characteristics they used to describe girls and boys were very similar.

It appears that teachers are very aware of whether the child they are interacting with is a boy or a girl. However, they don't think that there are important differences between girls and boys that should be attended to as they make instructional decisions. Boys just appear to be more salient in the teachers' minds: teachers appear to react to pressure from students, and they get more pressure from boys. Interventions designed with this finding in mind would be very different from interventions that assume that teachers are sexist.

Another student, Carolyn Hopp (1994), who is currently finishing her dissertation, is concerned with what happens in cooperative small groups that influences the learning of mathematics, particularly the learning of complex mathematics like problem solving. While this work is still preliminary, it appears that boys and girls engage in different mental activities during cooperative problem solving, and the impact of working in cooperative groups on their learning may be quite different depending on what mental activity is engaged in during the cooperative activity. Just working in small groups does not insure that girls will learn mathematics. It depends upon what goes on as the groups engage in cooperative activity. Thus, while research conducted from a cognitive science perspective is still in its infancy as far as gender and mathematics are concerned, such studies can provide knowledge that will help us understand the underlying mechanisms that have resulted in gender differences in mathematics.

Consider the case of the relationship between confidence in learning mathematics and the actual learning of mathematics. It has been assumed for at least two decades that lower confidence contributes to gender differences in mathematics. (In self-defense, if you read my writing carefully or listen to what I have said, I have never said that. In fact, I have often said that we do not know how confidence influences learning.) Perhaps, a careful study of males' and females' perception of what has influenced their development of confidence in doing mathematics, and how their confidence has impacted on their study and learning of mathematics might give us better insight into the relationship of the two. Or, studying the impact that teachers' perception of the confidence of their students has on decisions that teachers make during mathematics instruction might provide deeper insight into teacher-student interactions. Knowledge derived from a cognitive science perspective has enabled some teachers to eliminate gender differences in mathematics. Carpenter and I have been investigating how knowledge of the universals of children's thinking about whole number arithmetic could be used in classrooms and whether this knowledge would make a difference in what teachers did and how children learned (Carpenter & Fennema, 1992). We called the project Cognitively Guided Instruction (CGI) and we continue to investigate it today. Basically, we shared with teachers what we knew about the universals of children's learning, enabled them to become secure in that knowledge, and supported them as they applied the knowledge in their primary classrooms. Briefly, we found that teachers could acquire this knowledge of universals and use it in classrooms to make instructional decisions about individual children. CGI teachers' beliefs about children changed and children in CGI classrooms have learned mathematics in excess of anything we expected.

At the beginning of our first study, before teachers had learned about children's thinking, we found that first-grade boys were better problem solvers than first-grade girls. In succeeding studies of children in Grades 1-3 who have spent a year with teachers who know and understand children's thinking, we have found variable gender differences. Often, no differences exist: sometimes they are in the boys' favor, and at other times they are in the girls' favor. It appears that when teachers make instructional decisions based on their knowledge of individual children, overall gender differences are not found. It also appears that among certain teachers, although they are few in number, gender differences in favor of boys usually exist across classrooms and years; and, among even fewer teachers, differences in favor of girls are found across years. We are just beginning to try to ascertain whether we can identify components of their classrooms or cognitions that encourage the development of these gender differences in certain teachers' classrooms. Thus, it appears that research utilizing a cognitive science perspective can be helpful in gaining an understanding of gender and mathematics. It enables us to go beyond surface knowledge and overt behavior to develop an understanding of underlying mechanisms. With this understanding, future educational directions can be identified.

Feminist Perspectives

Included in the broad group of approaches to research that I am calling feminist are perspectives that have been defined as feminist methodologies, feminist science, feminist epistemologies, and feminist empiricism. I am not an expert on these, and, thus, will not try to provide a thorough discussion. (For that, I refer you to Bleier, 1984; Campbell & Greenberg, 1993; Harding, 1987; and Shakeshaft, 1987.) While within the work of scholars included in this tradition there are marked differences that go beyond the purview of this paper, they do share a commonality. Without exception, they focus on interpreting the world and its components from a feminine point of view, and the resulting interpretations are dramatically different from what exists today.

Feminist scholars argue very convincingly that most of our beliefs, perceptions, and scholarship, including most of our scientific methodologies and findings, are dominated by male perspectives or interpreted through masculine eyes. According to feminist scholars, because females have been omitted, the view of the world as interpreted through masculine perspectives is incomplete at best, and often wrong. If women's actions and points of view had been considered over the last few centuries, according to many of these feminist scholars, our perceptions of life would be much different today.

A basic assumption of feminist work is that there are basic differences between females and males that are more prevalent than the obvious biological ones and that result in males and females interpreting the world differently. Although many of these scholars present convincing arguments about how the world influences males and females differently, most feminist writers I have read are basically uninterested in whether or not such differences are genetic or related to socialization. It is enough for them that the differences exist. These differences influence one's entire world and life. For those who are just thinking about this idea for the first time, I recommend that you find a little book called *The Yellow Wallpaper* (Gilman, 1973). Written about 100 years ago, it gives a picture of one woman's view of her world and, at the same time, the picture of that same world from her husband's viewpoint. Both views impress the reader with their accuracy - and they are dramatically different.

These scholars work in several areas, almost all of them outside mathematics education. Some are trying to interpret a basic discipline of concern (such as biology or history) from a female, rather than a male, point of view. They argue that almost all scholarship, including the development of what is called science and mathematics, has been done by men and from a masculine view point, utilizing values that are shared by men, but not by women. Those major bodies of knowledge that appear to be value-free and to report universal truth are in reality based on masculine values and perceptions. Since males' roles and spheres in the world have been so different from females' roles and spheres (Greene, 1984), these bodies of knowledge do not reflect 50% of human beings and thus are incomplete and inaccurate. Jim Schuerich (1992) has suggested that a feminist science is better than a value-free science. To support this, he draws from Charol Shakeshaft's (1987) work on educational administration and Carol Gilligan's (1982) work on the development of moral judgment. Each of them has demonstrated quite conclusively that research on male-only populations has produced results that were not only incomplete, but were wrong.

The idea of masculine-based interpretations in areas like history or literature, and even in medical science, is not too difficult to illustrate, nor even to accept. Many conclusions in medical research have been based solely on male subjects; their inaccuracy is easy to illustrate. History has been presented as if most of our ancestors were male and as if important things happened predominately to males in the public arena. The use of male names by female writers in order that their writing be accepted, or even published, is commonly known. Does the prevalence of this attitude apply to mathematics and if so, how? Can mathematics be seen as masculine or feminine? Is not mathematics a logical, value-free field? The idea of a masculine or a feminine mathematics is difficult to accept and to understand, even to many who have been concerned about gender and mathematics. A few people are working to explicate what a gendered mathematics might be - in particular, Suzanne Damarin (in press), Zelda Issacson (1986), and Judith Jacobs (in press), who are struggling to define what a feminist approach to the study of mathematics education might be.

One way to approach the problem of a gendered mathematics is not to look at the subject, but to examine the way that people think and learn within the subject. This has been done in other disciplines: the work of Belenky and her colleagues (Belenky, Clinchy, Goldberger, & Tarule, 1986) in identifying women's ways of thinking and knowing has been provocative as we consider this question. Many within the field of gender and mathematics studies have interpreted this kind of basic research as necessary if we are to identify what female-friendly instruction might be - e.g., the greater inclusion of cooperation rather than of competition in classrooms. Others have argued for single-sex schools oriented to the mathematics instruction of females. Running through these suggestions, it seems to me, is a basic belief that females learn differently and perform differently in mathematics than do males.

Another theme that informs many of the feminist perspectives is the necessity for women's voices to be heard (Campbell & Greenberg, 1993). To these scholars, it is not enough that researchers identify important questions, which are then studied objectively using a positivist approach. Females must have a hand in identification of the questions; females' life experiences become critical, so that the world can be interpreted from a female perspective. So we see subjects as co-investigators, women reporting their own experiences, and women as the main subjects under investigation helping to interpret results. There are not many of these studies available currently in mathematics education, but I predict that we shall see increasing numbers of them as the importance of female voices is recognized.

It is too early to be able to assess the impact that studies using feminist methodologies will have on our understanding of gender and mathematics, both the identification of the problem and its solutions. It appears logical to me that, as I try to interpret the problem from a feminist standpoint, it is different from what I focussed on earlier. Instead of interpreting the challenges related to gender and mathematics as involving problems associated with females and mathematics, I begin to look at how a male view of mathematics has been destructive to both males and females. I begin to articulate a problem that lies in our current views of mathematics and its teaching. I am coming to believe that females have recognized that mathematics, as currently taught and learned, restricts their lives rather than enriches them.

Whatever our own value position about feminism and mathematics, I believe that we need to carefully examine how feminist perspectives can add enriched understanding to our knowledge of mathematics education. And, indeed, we should be open to the possibility that we have been so enculturated by the masculine dominated society we live in that our belief about the neutrality of mathematics as a discipline may be wrong, or at the very least, incomplete. Perhaps we have been asking the wrong questions as we have studied gender and mathematics. Could there be a better set of questions, studied from feminist perspectives, that would help us understand gender issues in mathematics? What would a feminist mathematics look like? Is there a female way of thinking about mathematics? Would mathematics education, organized from a feminist perspective, be different from the mathematics education we currently have?

Suzanne Damarin (in press) has stated that we need to "create a radical reorganization of the ways that we think about and interpret issues and studies of gender and mathematics." Many scholars believe that only as we do this will we be fully able to understand gender issues in mathematics. Perhaps my beginning to believe that the decision by females not to learn mathematics nor enter mathematics-related careers because mathematics has not offered them a life they wish to lead is an indication that my old view about learning and teaching mathematics, as well as about gender and mathematics, was immature and incomplete. I am beginning to believe that an examination of what the female voices in the new research are saying will help me-and perhaps others-to understand teaching, learning, gender, and mathematics better.

New Research Perspectives - Some Contrasts

Cognitive science and feminist perspectives, while sharing surface similarities, are based on dramatically different assumptions about females and males. These assumptions dictate the questions that are addressed, how studies are designed, and how evidence is interpreted. They are assumptions that are more far-reaching than issues of scholarship; they influence how we view the entire issue of gender and mathematics. What is the magnitude and impact of differences between females and males? Are males and females fundamentally different, so that all decisions about mathematics and understanding gender and mathematics need to be made on the basis of these differences? Or are males and females fundamentally the same, with the exception of their biological differences, and are these differences irrelevant with respect to mathematics? Cognitive science research, as it identifies universals, would suggest that looking at the world through either feminine or masculine eyes does not make sense. Feminist perspectives suggest just the opposite: female/male differences permeate the entirety of life and must be considered whenever scholarship is planned.

The implications of these assumptions are dramatic, in both doing and understanding research, as well as work in the field of gender and mathematics. Each individual should think deeply about his or her own beliefs and reinterpret knowledge about gender and mathematics in relation to these beliefs or assumptions.

In Conclusion

Research has provided rich documentation of and knowledge about variables that are related to gender and mathematics, and moderate change in what has happened to females within mathematics education has occurred partly because of this scholarship. We need to continue research that documents the status of gender differences as they exist. However, research, as we know it, must be supplemented with new types of scholarship focussed on new questions and carried out with new methodologies. Such scholarship will help in the identification of important emphases for further new research; it will also ensure that women's voices will become a major part of all educational scholarship.

While I have chosen to focus this paper on research as I perceive it, there have been other forces at work during the same time that our research knowledge has been accumulating. Many innovative interventions have been developed, based on the intuitive knowledge of concerned individuals. Mathematicians, educators, teachers, and parents have become aware of the issues related to gender and mathematics. We have come a long way. We have a long way to go to accomplish equity in mathematics education.

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References

Adetula, L. O. (1989). "Solution of simple word problems by Nigerian children: Language and schooling factors." *Journal for Research in Mathematics Education,* 20, 489-497.

Anon. (in progress). "Citation Classic." *Current Contents* .

Belenky, M., Clinchy, B., Goldberger, N., & Tarule, J. (1986). *Women's Ways of Knowing: The Development of Self, Voice and Mind.* New York: Basic Books.

Bleier, R. (1984). *Science and Gender: A Critique of Biology and its Theories on Women.* New York: Pergamon Press.

Brown, C., & Borko, H. (1992). Becoming a mathematics teacher. In D.A. Grouws (Ed.), *Handbook of Research on Mathematics Teaching and Learning: A Project of the National Council of Teachers of Mathematics* . New York: Macmillan.

Campbell, P., & Greenberg, S. (1993). Equity issues in educational research methods. In S. K. Bilken & D. Pollard (Eds.), *Gender and Education: Ninety-second Yearbook of the National Society for the Study of Education.* Chicago: University of Chicago.

Carpenter, T. P., & Fennema, E. (1992). "Cognitively guided instruction: Building on the knowledge of students and teachers." In W. Secada (Ed.), *Curriculum Reform: The Case of Mathematics Education in the United States.* Special issue of *International Journal of Educational Research* , (pp. 457-470). Elmsford, NY: Pergamon Press, Inc.

Carpenter, T., Moser, J., & Romberg, T. (1982). *Addition and Subtraction: A Cognitive Perspective.* Hillsdale, NJ: Lawrence

Erlbaum Associates.

Casserly, P. (1980). "Factors affecting female participation in advanced placement programs in mathematics, chemistry, and physics." In L. Fox, L. Brody, & T. Tobin (Eds.), *Women and the Mathematical Mystique.* Baltimore: Johns Hopkins University Press.

Damarin, S. (in press). Gender and mathematics from a feminist standpoint. In Secada, W. S., Fennema, E., & Byrd, L. *New Directions for Equity in Mathematics Education*. Cambridge University Press.

Eccles, J. S., & Blumenfeld, P. (1985). "Classroom experiences and student gender: Are there differences and do they matter?" In Wilkinson & C. B. Marrett (Eds.), *Gender Influences in Classroom Interaction*. New York: Academic Press.

Fennema, E. (1974). "Mathematics learning and the sexes: A review." *Journal for Research in Mathematics Education,* 5(3), 126-139.

Fennema, E., & Leder, G. (Eds.). (1990). *Mathematics and Gender: Influences on Teachers and Students.* New York: Teachers College Press.

Fennema, E., & Peterson, P. (1985). "Autonomous learning behavior: A possible explanation of gender-related differences in mathematics." In L. C. Wilkinson & C. B. Marrett (Eds.), *Gender-related Differences in Classroom Interactions.* Academic Press, pp. 17-35.

Fennema, E., & Peterson, P. L. (1986). "Teacher-student interactions and sex-related differences in learning mathematics." *Teaching and Teacher Education*, 2(1), 19-42.

Fennema, E., Peterson, P. L., Carpenter, T. P., & Lubinski, C. A. (1990). "Teachers' attributions and beliefs about girls, boys, and mathematics." *Educational Studies in Mathematics,* 21(1), 55-65.

Fennema, E., & Sherman, J. (1977). "Sex-related differences in mathematics achievement, spatial visualization, and affective factors." *American Educational Research Journal,* 14(1), 51-71.

Fennema, E., and Sherman, J. (1978). "Sex-related differences in mathematics achievement and related factors: A further study." *Journal for Research in Mathematics Education,* 9(3), 189-203.

Fennema, E., & Tartre, L. (1985). "The use of spatial visualization in mathematics by boys and girls." *Journal of Research in Mathematics Education,* 16(3), 184-206.

Fennema, E., Wolleat, P., Becker, A., Pedro, J. D. (1980). "Multiplying options and subtracting bias. An intervention program composed of four videotapes and facilitators' guides." National Council of Teachers of Mathematics. Reston: VA.

Gilligan, C. (1982). *In a Different Voice: Psychological Theory and Women's Development.* Cambridge, MA: Harvard University Press.

Gilman, C. P. (1973). *The Yellow Wallpaper.* Afterword by E. R. Hedges. New York: Feminist Press.

Greene, M. (1984). "The impacts of irrelevance: Women in the history of American education." In E. Fennema & M. J. Ayer (Eds.), *Women and Education: Equity or Equality?* Berkeley, CA: McCutchan.

Hanna, G. (1989). "Mathematics achievement of girls and boys in grade eight: Results from twenty countries." *Educational Studies in Mathematics*, 20(2), 225-232.

Harding, S. (1987). *Feminism and Methodology.* Bloomington, IN: Indiana University Press.

Hopp, C. (1994). "Cooperative learning and the influence of task on learning of mathematics." Unpublished doctoral dissertation, University of Wisconsin-Madison.

Hyde, J. S., Fennema, E., & Lamonj, S. J. (1990). "Gender differences in mathematics performance." *Psychological Bulletin*, 107, 299-324.

Hyde, J. S., Fennema, E., Ryan, M., & Frost, L.A. (1990). "Gender differences in mathematics attitude and affect: A meta-analysis." *Psychology of Women Quarterly,* 14, 299-324.

International Commission on Mathematics Instruction. (1992). Study document for Gender and Mathematics Conference.

Isaacson, Z. (1986). "Freedom and girls' education: A philosophical discussion with particular reference to mathematics." In L. Burton (Ed.), *Girls into Maths Can Go*. London: Holt, Rinehart & Winston.

Jacobs, J. (in press). "Feminist pedagogy and mathematics." In *International Reviews on Mathematical Education.*

Jacobs, J. E., & Eccles, J. S. (1985). "Gender differences in math ability: The impact of media reports on parents." *Educational Researcher,* 14 (3), 20-25.

Koehler, M. S. (1990). "Classrooms, teachers and gender differences in mathematics." In E. Fennema & G. Leder (Eds.), *Mathematics and Gender.* New York: Teachers College Press.

Leder, G. C. (1992). "Mathematics and gender: Changing perspectives." In D. A. Grouws (Ed.), *Handbook of Research on Mathematics Teaching and Learning:* A Project of the National Council of Teachers of Mathematics. New York: Macmillan.

Leder, G.C. (1982). "Mathematics achievement and fear of success." *Journal for Research in Mathematics Education,* 13(2), 124-135.

Maccoby, E. E., & Jacklin, C. N. (1974). *The Psychology of Sex Differences.* Stanford University Press, Stanford, CA.

Olivier, A., Murray, H., & Human, P. (1990). "Building young children's mathematical knowledge." In G. Booker, P., Cobb & T.N. Mendicuti (Eds.), *Proceedings of the Fourteenth International Conference for the Psychology of Mathematics Education,* Vol. 3 (pp. 297-304). Mexico.

Peterson, P. L., & Fennema, E. (1985). Effective teaching, student engagement in classroom activities, and sex-related differences in learning mathematics." *American Educational Research Journal* , 22(3), 309-335.

Reyes, L. H., & Stanic, G. M. A. (1988). "Race, sex, socioeconomic status and mathematics." *Journal for Research in Mathematics Education,* 19(1), 26-43.

Schuerich, J. (1992). "Methodological implications of feminist and poststructuralist views of science." *The National Center for Science Teaching and Learning Monograph Series. Number 4.*

Secada, W. S. (1991). "Degrees of bilingualism and arithmetic problem solving in Hispanic first graders." *Elementary School Journal,* 52, 306-316.

Secada, W. S. "Race, ethnicity, social class, language, and achievement in mathematics." In D. A. Grouws (Ed.). *Handbook of Research on Mathematics Teaching and Learning.* New York: Macmillan.

Shakeshaft, C. (1987). *Women in Educational Administration.* Newbury Park, CA: Sage Publications.

Sherman, J. S., & Fennema, E. (1977). "The study of mathematics among high school girls and boys: Related factors." *American Educational Research Journal,* 14(2), 159-168.

Stanley, J., & Benbow, C. (1980). "Sex differences in mathematical ability: Fact or artifact." *Science,* 210, 1262-1264.

Walberg, H., & Haertel, G. (1992). "Educational psychology's first century." *Journal of Educational Psychology,* 84(1), 6-19.

Weisbeck, L. (1992). "Teachers' thoughts about children during mathematics instruction." Unpublished doctoral dissertation, University of Wisconsin-Madison.

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