Nature, neglect & nuance: changing accounts of sex, gender and mathematics

Jo Boaler & Tesha Sengupta-Irving, Stanford University.

In *Gender and Education. International Handbook, 2006.*

INTRODUCTION

There is a popular idea, held by members of the public and supported by media in a number of different countries, that girls are not as good as boys in mathematics and science. This outdated perception has a significant effect on the gender relations it claims to report and it is one reason we argue gender and mathematics remains a critical field in education. It is both curious and troubling to note that few researchers study or consider gender and mathematics as an academic field in the 21st century, despite the careful paths laid down by our predecessors in the academy. Part of the reason for the lack of attention is the increased performance of girls who now achieve at the same or higher levels than boys in a number of countries. But we will argue in this chapter that girls and women are systematically discouraged from entering mathematical and scientific fields and that research can provide important insights into the sources of such inequities. Controversially, perhaps, we will also argue that one of the sources of girls' discouragement over the years has been the research produced on gender and mathematics, some of which has inadvertently positioned girls in ways that are counter-productive to their advancement. In reviewing research, writing and societal views on the issue of gender and mathematics we will consider different achievement and participation patterns in mathematics and gender in the 2000s, the different lenses that have been used to consider gender and mathematics and newer, more productive ways in which gender may be understood and analyzed.

1. GENDER AND MATHEMATICS: PARTICIPATION AND PERFORMANCE PATTERNS IN THE 21ST CENTURY

When Larry Summers, president of Harvard University, speculated that 'innate differences' (Bombardieri, 2005, p1) between men and women caused fewer women to succeed in science and math and that such differences impacted school performance and participation beyond school, he sparked a media frenzy in the United States. Dramatically, the issue of gender and mathematics took center stage as journalists rushed to cover the story, drawing from wide ranging sources to support or refute Summers' claim. Most journalists began their investigations of the genetic question by asking – is he right? Are girls behind in mathematics and science? Further, are performance differences in school the reason for women's low participation at higher levels? These issues are important to consider and we precede our review of gender research with some answers to these questions, drawing upon data from two countries: the US and England. Despite the limiting quality of such a small number of well resourced cases, they do show interesting and different patterns of gender equity that are helpful in considering issues for students from a wider group of countries. Hanna's (1996) edited collection gives a broader look at issues of gender and mathematics in a wider range of countries across the world.

In considering whether girls perform at significantly lower levels than boys in mathematics, the US provides an interesting case in point as some tests show gender differences while others do not. Janet Hyde, Elizabeth Fennema and Susan Lamon (1993) produced a meta-analysis of gender differences in the nineties, and even at that time – over ten years ago – they found a minimal difference. They drew from over 100 studies involving 3 million subjects and derived an effect size of +0.15 standard deviations. Hyde and colleagues argued that gender differences were too small to be recognized as meaningful, and concluded that they have been overplayed and glamorized in the media which has contributed to a discourse of difference that has itself created differences in the achievement of girls and boys.

The small performance differences between girls and boys that continue in the US take place on the Scholastic Assessment Test (SAT) (Rosser, 1992) and the Advanced Placement (AP) examinations (Coley, 2001). These two assessments fuel a continued discourse concerning the inadequacy of women and girls in mathematics. Interestingly England, a country with similar resources spent on education, shows a different pattern of results that has shifted dramatically over time. In England almost all students take a mathematics examination at age 16, the General Certificate of Secondary Education (GCSE) in mathematics. As mathematics is compulsory to age 16 equal numbers of boys and girls take this examination. In the 1970's boys used to pass the mathematics GCSE examination (then called the 'O-level') in higher numbers and attain more of the highest grades; in the 1990's girls and boys passed the exam in equal numbers but boys achieved more of the highest grades. By the 2000's girls were passing the exam at higher rates than boys and attaining more of the highest grades. In 2003/4 for example 51% of the A-C grades went to girls (n=318,300, DFES, 2004). At ages16-18 students who select to stay in education may choose a small number of subjects in which to specialize (usually three). The mathematics A-level course is comparable to the AP courses in the US, but it includes higher-level work. At the end of that course students also take a terminal examination. At A-level the participation of girls drops dramatically; although girls attained 51% of the top GCSE grades in 2004, they made up only 37% of the A-level cohort. Despite this their achievement was strong and the results on the examination in 2003/4 showed that they attained slightly better results than boys: 96% of boys passed the examination and 39% attained the highest grade of A, compared with 97% of girls who passed the examination with 41% attaining the highest grade. In England girls now outperform boys in all subjects, including mathematics and physics, to GCSE and A-level and they now attain more of the highest grades in demanding high-level examinations.

But whilst the relative performance of the girls in England is higher than the US, the participation of girls is lower. For example, in 2004 only 37% of the A-level cohort in England was female compared to 48% of the AP calculus cohort in the US. In the US in 2000, 48% of mathematics undergraduate degrees went to women (statistical research center, 2003), and 48% of the AP cohort were women; in England the proportion of women undergraduate students was 39% (dti, 2005) and 37% of A-level students were women. The similarity in participation rates at school and university levels suggests a direct link between the two with lower participation at university reflecting choices made in school. In both countries the proportion of women who are represented at higher levels is much smaller. In the US in 1990 18% of mathematics PhDs went to women (Chipman, 1996), and in 2000 the figure was 27% (Herzig, 2004a). Women's presence in occupations and professions that are mathematical and scientific is also extremely low. In 2000 in the US for example, 9% of engineers were women. Herzig (2004b) has produced systematic evidence of the ways in which the climate of university mathematics departments may deter the participation of women and minority students.

In summary, data from these two countries show two patterns that are important and probably generalizable. The first is the positive achievement of girls and women, something that is being replicated across the globe in countries in which girls have equal access to education. Japan, Sweden and Iceland are other examples of countries in which girls outperform boys in mathematics. These examples should be sufficient to dispel any lasting ideas about the genetic superiority of boys. That girls are able to achieve such results within societies that maintain sexist images and ideas about genetic disadvantage shows the capability and resilience of girls. The second pattern that emerges from the data and that pertains in other countries (see also Grevholm, 1996; Spitaleri, 1996; Bosch & Trigueros, 1996) is the relatively low participation of girls and women in the mathematical sciences, which becomes more severe as the level increases (Herzig, 2004b).

These data come from two well resourced countries and the patterns of achievement and participation shown are higher than for many other countries, particularly those with less resources and/ or more overtly sexist regimes. Yet even these two countries show some clear issues that need attention, specifically the under representation of women even when they are achieving at high levels. We started this section questioning whether there are important performance differences at secondary school that may explain women's low participation at post-graduate and professional levels. Neither data from England nor the US support this explanation as university participation is almost equal in the US and in England, and where it is not, girls are opting out of mathematics *despite* their advanced performance in secondary school. The low participation of girls and women at high levels of mathematics and related fields is an important issue and it is one that probably begins in school, despite the high achievement of girls, and becomes more accentuated as levels increase. This phenomenon requires sophisticated understandings of the issues facing girls and women in mathematics classrooms (see for example, Herzig, 2004a, b, Mendick, 2005a,b) and more complex analyses than are generally offered in the media (Leder, 1996). In contributing to such analyses we will spend some time reviewing recent and important work on gender and mathematics.

REVIEWING RESEARCH ON GENDER AND MATHEMATICS

.

Our review of research falls into six areas separated by the location of researchers' attention as well as the different methods and lenses employed by equity researchers. In considering these different lenses we will make some points about the usefulness of the lenses themselves in impacting opportunities for equity.

Genetic differences

Research that has investigated genetic differences in mathematics performance has come at two distinct times. In the 1980's Benbow and Stanley (1980) reported that boys achieved at half a standard deviation higher than girls in populations of students selected from among the top 2-3% of students (1980, p1262). The authors controversially claimed that the differences they found reflected superior mathematical ability among boys. This claim has subsequently been widely discredited but the original report, which appeared in SCIENCE magazine, caused considerable damage. Eccles & Jacobs (1985) found that the Benbow and Stanley report significantly lowered mothers' expectations of their daughters' potential with mathematics.

A more recent line of research that may shed light on the question of innate differences comes from advances in brain imaging technology. O'Hara (2005) summarized the emerging research on brain patterns and reported that the most consistent result from studies of memory shows females to have a better 'working memory'. In tests of visual-spatial abilities males have been found to be faster navigators but performances on tests have been equal. In the area of language, researchers have found differential patterns of brain processing but no performance differences between women and men. In the area of mathematics, the most relevant for our review, there have been a limited number of imaging studies and to date gender differences have not been considered. In summary, O'Hara concluded that brain imaging is a new field with no clear results. Where studies have been conducted they have tended to show some differential processing in the brains of men and women with no impact on performance. Another researcher working in this field, Louann Brizendine, argues that because girls develop language skills faster than boys, boys gravitate towards toys that require minimal verbal interaction, such as building blocks and train sets and that help them in their mathematical development. 'These cognitive gaps between boys and girls close during high school, Brizendine said. But here's the problem. By high school boys have spent years reinforcing and strengthening their skills in math and science and girls in language arts' (Ryan, 2005, pB7). Thus brain research may explain the few mathematical differences that exist not by showing any mathematical inferiority of girls but different developmental stages that support certain types of activity over others.

Studies of brain processing do not support the idea that girls and women are genetically inferior to boys and men in their mathematical potential, yet this idea is one that appeals to many. The strength and breadth of this belief stands independent of evidence and is vastly out of proportion to any data that has ever been produced. Such ideas are harmful, they concern the intellectual potential of young people and they have contributed to the gender differences that prevail in society with men continuing to dominate mathematical and scientific fields.

Affect and Attitude: 'girls will be girls'. A large and important body of research in gender and mathematics has focused upon the affective and attitudinal beliefs of girls that impact their participation in mathematics. Researchers have studied the differences between boys and girls in categories such as anxiety, fear of success, confidence, self-concept, motivation and perceptions of the usefulness of mathematics (Leder, 1982; Hart, 1989; Ethington, 1992; Seegers & Boekarts, 1996; Koehler ,1990). The findings from such work suggest that girls differentially experience and engage in mathematics classes. For example, Hart (1989) found boys interacted more with their teachers publicly (and therefore receive more positive public evaluation) than girls did, despite their confidence levels in the subject. Ethington (1992) found that the achievement of boys in mathematics classes was influenced more by prior achievement and value for the subject than girls, who were influenced more by their perceptions of the difficulty of the subject and the idea that it is a subject where males dominate. One of the most important methodological contributions that came from this area of research was the

Fennema-Sherman Attitude Scale developed in 1976 that characterizes students' attitudes towards mathematics. There is evidence, from this and related studies, that girls have lower self images in mathematics as well as beliefs that mathematics is more suited to males. Such ideas, fueled by media reports (Jacobs & Eccles, 1985) are likely to suppress the participation of women and girls in mathematical fields. Attitudinal studies have provided valuable insights into the reasons for the relatively low participation of women and girls in mathematics. The legacy of such research lies in the various intervention programs that promote the participation of girls in mathematics and science in schools today. Indeed these programs and their accompanying research studies illustrate the powerful potential for increased performance and participation of girls in mathematics through a deliberate focus on their individual needs (Fennema, Pedro, Wolleat & Becker, 1981; Koontz, 1997). An additional, less fortunate outcome of such work is the perpetuation of ideas about female inadequacy. Tendencies such as lack of confidence, anxiety and failure attributions were generally presented as properties of girls, rather than as responses co-produced by particular working environments. Thus proposed interventions aimed to change the girls so that they became less anxious, more confident - *essentially* more masculine. In such programs, the responsibility for change was laid at the feet of the girls and problems with mathematical pedagogy and practice, and with the broader social system, were not addressed. An example of research that positions the 'problem' within girls comes from Carol Dweck (1986) who has produced a number of influential analyses in which she concludes that girls, particularly those she terms 'bright' girls, have maladaptive motivational patterns, that include avoiding high risk learning situations and preferring situations in which they are sure to succeed. She claims that students with maladaptive patterns seek situations that will lead to correct answers, rather than those that are challenging and provide opportunity for learning. Dweck offers 'maladaptive' tendencies as a reason for the lower mathematical performance of some girls, particularly at advanced levels, but she treats these motivational patterns as inherent characteristics of girls, that exist outside the settings in which girls are taught. This seems to be a fundamental flaw as motivations must surely be highly situated. If we were to consider the tendencies Dweck noticed among 'bright girls', outside of their setting, we might conclude that the tendencies were indeed 'maladaptive' in the sense that they were unproductive. But if we consider the system in which students were learning, we may view the tendencies of girls as highly adaptive. The majority of 'bright' girls are taught mathematics in high ability groups in which the attainment of correct answers, at a fast pace, is what is valued (Boaler, 1997b). In such an environment choosing to seek situations that will lead to correct answers, seems sensible and highly *adaptive*. The notion of adaptivity – central to theories of natural selection – rests upon environmental responsiveness, and the idea that 'girls' have maladaptive tendencies contravenes that basic premise. A different analysis would consider the constraints and affordances (Gibson, 1986; Greeno & MMAP, 1998) provided by the environments in which girls work, that lead to such responses.

The difference between the two approaches we have mentioned – one that considers the girls as maladaptive, the other that focuses on the teaching environments which produce such tendencies – is that the first would lead to recommendations to change the girls. The second interpretation would lead to recommendations to change the teaching environments in which students are working – environments that produce motivational patterns that are unproductive for learning. Another characteristic of the area of research that we have termed 'girls will be girls' is its reliance on a distinct dichotomizing of boys and girls. Within much of the research, achievement and participatory patterns were explained through comparisons with boys. Thus girls' achievements in mathematics became their *under*achievement in mathematics, without challenge, just as their adaptivity became their *mal*adaptivity. At the same time, boys' achievements, participation and behaviors were implicitly positioned as 'normative' and the benchmark against which girls were understood. By emphasizing comparative analyses within the field, researchers were actively distracted from focusing on girls' perspectives and responses as legitimate measures of their learning experiences as well as the educational practices that more and less inadvertently produced gender inequities. As a result this area of research did not consider questions such as: what do girls bring to mathematics? What can they tell us about their experiences, which might provide greater insight into inequities? These are the types of questions – questions that outright reject a 'normative' male benchmark – that have rarely been asked.

Women's ways of knowing

Probably the most famous and influential example of work that rejected male benchmarks came from Carol Gilligan (1982), who showed through her work on moral judgments among women how seemingly normative benchmarks replicate and narrate a sexist notion that human development is modeled by male development. Her work, termed 'difference feminism' (DeBare, 2004, p199) and that of her successors, paved the way for more research by, with and for women.

Belenky, Clinchhy, Goldbergy & Tarule (1986) developed the educational implications of Gilligan's work by proposing 'stages' of knowing from a longitudinal interview study of women across multiple sites of formal education. In their analysis the authors proposed a five-staged approach of the ways women come to 'know' offering a progression from uncritical to critical ways of knowing. The authors suggest that a system of 'connected knowing' better represents women while a system of 'separate knowing' better represents men. Elements under the rubric of 'separate knowing' include: logic, rigor, abstraction and deduction while 'connected knowing' reflects intuition, creativity, hypothesizing and induction (Becker, p.167). Becker (1995) and Boaler (1997a) explored these notions in mathematics education and Becker suggested that mathematics classes that reinforce connected knowing would, for example, 'share the process of solving problems with students, not just the finished product of proof' (p169) and that more emphasis would be placed on finding different ways to solve problems. This argument is supported by research that shows that girls often prefer cooperative and discussion based learning environments, rather than individualized or competitive environments (Fennema & Leder, 1990; Boaler, 2002a,b).

Sexism and Sex-Stereotyping A fourth area of important research in gender and mathematics concerns teaching environments and curricular materials. This area of research explores the possibility that sex stereotyping in textbooks or sex-based discrimination by teachers affects the performance and participation of girls and women in mathematics (Forbes, 1996; Niederdrenk-Felgner, 1996). In this way the 'problem' that requires intervention is no longer the girls but the textbooks and teacher-student interactions that girls are exposed to in their mathematics classes. There have been several important outcomes from this line of inquiry including greater attention to gender representations in instructional materials (Burton, 1990), greater interest in the benefits of single-sex schooling (Marjoram, 1994; DeBare, 2004), and heightened awareness of teacher beliefs and bias in classroom interactions (Becker, 1981; Hart, 1989; Leach, 1994; Walden & Walkerdine, 1985; Walkerdine, 1989). The increased access girls now have to mathematics in classrooms is probably due to research that increased the awareness of teachers about gendered interactions in classrooms in the 1980's and later years (Spender, 1982). Typical findings in this area of research showed that sex-differences prevailed in the interactions of students and teachers that generally favored boys, with boys receiving more attention, reinforcement and positive feedback from mathematics teachers (Becker, 1981). This work moved from the survey data that characterized affect studies, to quantitative data on student-teacher interactions and qualitative observations of environments. As researchers became more aware of the factors that could influence girls' participation and achievement intervention areas moved from the student to the teacher and the teaching environments, as evidenced by the nature and quality of their interactions. Whereas moving the analytical home from girls to teachers unburdened the girls, it was equally clear that the 'blame' could not be laid on the teachers alone. As Hart (1989) remarked, 'Any explanation that focuses on the teacher alone or on the student alone is too simplistic' (Hart, 1989, p257).

A Feminist mathematics

A different perspective on gender and mathematics research considers the nature of the discipline and the ways that mathematics, the subject, may be gendered. Such research takes up Johnston's proposition that, 'Perhaps we don't take seriously enough the voices that say, again and again, 'but it doesn't make sense', and 'what's the point?' Perhaps what they are saying simply is true. Perhaps mathematics, their mathematics, secondary-school mathematics, doesn't make sense. Perhaps the fault is in the mathematics, and not the teaching, not the learning, not the people' (Johnston, 1995, p226). This body of work begins with a basic premise: mathematics is a system of knowledge, a product of human thought, discovery and practice. In this way, understanding that mathematics is an informal, subjective exploration of the natural world is honest to its history. Yet mathematics in schools belies this truth and presents a formalized, 'objective,' and discrete system of skills and rules that is largely void of the context that gave rise to it. Feminist scholars suggest that a transformation of mathematics from its organic roots to a more synthetic rendering has detrimental implications because it purposely obscures power, privilege and the gendered nature of the discipline to its teachers and learners alike.

Scholars in this field of research generally advocate for a feminist conception of the discipline. Leone Burton, for example, asks, 'If the body of knowledge known as mathematics can be shown to have been derived in a manner which excluded non-Europeans and their mathematical knowledge, why not conjecture that the perceived male-ness of mathematics is equally an artifact of its production and its producers?' (Burton, 1995, p213) As an alternative, positioning mathematics within a feminist epistemology enriches the discipline while also enabling historically marginalized communities, such as women, to feel they too have the power to author and own it.

Heather Mendick has produced a related line of work in exploring the tensions faced by young women who study mathematics. Mendick found strongly gendered perceptions of mathematics that influenced young women's decisions to continue in the discipline. Through narrative analysis Mendick (1995a,b) explores how women and men author their femininity and masculinity vis-à-vis the discipline and concludes that 'These discourses are oppositional and gendered; they inscribe mathematics as masculine, and so it is more difficult for girls and women to feel talented at and comfortable with mathematics and so to choose it and to do well at it' (1995a, p27-28). Although Mendick does not delve into the pedagogical roots of such perceptions, Marijolijn Witte offers this possibility: 'the emphasis on knowledge-transmission creates a system of mathematics education in which students are taught to mimic experts. Children learn knowledge which is not necessarily useful to them in their (personal, or local) situations, or for solving their own problems. They are under the control of the teacher or the school textbook, outside authorities in matters which they feel are also their own' (1995, p.238). Supporters of feminist epistemologies argue that they could serve to open the discipline to a greater range of communities as well as further the discipline by releasing it from narrowly prescribed paths.

Although Burton perceives little support for challenging the notion of 'objectivity' in mathematics, the work of feminist science writers such as Donna Haraway and Sandra Harding add support to the idea that we can offer richer accounts of the world by employing critical feminist stances. One of the outcomes of such work would be 'humane, responsive, negotiable and creative' (Burton, 1995, p222) mathematics taught to students in schools. Helen Longino, a philosopher, offers an alternative to the notion of feminist epistemology, whilst still employing feminist principles. Longino suggests a contrast between two positions, those of 'feminist science' and of ‘doing science as a feminist’. Rather than offering a different version of the discipline she argues that researchers should approach the many activities that ‘constitute science practice with a feminist sensibility’ (1987, p475). Longino lists six virtues, those of: empirical adequacy, novelty, ontological heterogeneity, complexity of relationship, applicability to current human needs and diffusion of power. She argues that feminist epistemology should be understood as practice rather than content and that it should shape the ways people approach their work in science and, we would argue, mathematics. Such approaches may of course lead to the positive changes in the disciplines that feminist mathematicians and scientists support.

No differences

A sixth body of work that considers gender in mathematics and science emanates from sociologists and others outside of education. In recent years an interesting counter-argument has been offered by researchers who refute the idea of innate differences and suggest that gender differences have been over-stated, exaggerated and grandized. Books such as ‘Same Difference: How gender myths are hurting our relationships, our children and our jobs’ (Barnett & Rivers, 2005) and ‘Deceptive Distinctions: Sex, gender and the social order’ (Epstein, 1988) argue against the *existence* of gender differences saying that the act of focusing upon gender is harmful and dichotomising, creating the very gender differences that researchers hope to eradicate. Barnett & Rivers (2005) rely on meta-analyses in their chapter on mathematics that amalgamate the achievement scores of boys and girls on many different tests. The three meta-analyses they show lead them to the conclusion that ‘math scores are roughly equivalent’. But whilst the ‘dichotomous’ argument carries the danger of essentialism and stereotyping, the counter-argument, that gender differences do not exist, runs a different risk – that of overlooking the harsh inequalities that pervade in many places and that cause unequal achievement and participation. The experiences of girls in mathematics classes in England provide a good case in point as it was the work of feminist scholars in the seventies and eighties, responding to small achievement differences, that probably enhanced the experiences of girls in mathematics classes. If researchers had overlooked the subtle differences that pertained between the sexes, these important achievements may not have been made.

DISCUSSION AND CONCLUSION: GENDER AS A COMPLEX INTERACTION

Perhaps the only conclusion that can be drawn from such a review of the field is that researchers need to consider many different factors that influence the performance and participation of girls and boys. Issues such as under-confidence, sexism in teaching environments, subject distortions and different cognitive preferences may all play a part in low performance and participation. Of course it is difficult for researchers to conduct studies that consider all variables but the neglect of such critical variables as teaching environments should give researchers considerable caution when drawing conclusions about the causes of differences. When Boaler conducted a study of two schools in England with different teaching approaches she found that one school produced gender differences and one did not (1997a, 2002a,b). Further, the gender differences seemed to come about through a preference for a different learning approach that girls displayed in traditional classrooms. Boaler points out that one conclusion could be that the girls at Amber Hill, a school employing a traditional approach, had preferences for certain ways of working and that these were not supported by the procedural approach of their school.

She notes that this interpretation has some validity, but it also has potential dangers as it locates the preferences that emerged *within the girls*. A different consideration of the data highlights the fact that gender responses were produced only within one of the two environments, suggesting that the underachievement and disaffection of girls from Amber Hill was a co-production, with the mathematics environments playing a central role. Indeed, the vastly different responses and achievements of girls within the two different school environments would support the idea that environments rather than institutionalized categories, such as gender or culture, may be a more productive site for the location of equity analyses. This positioning acknowledges the contributions of girls and pays attention to any preferences or approaches they bring, but the focus is on the environments and the ways they may promote or inhibit equity.

Relational analyses that locate gender as a response that emerges between people and environments may seem obvious and non-controversial, but they differ from traditional equity analyses in many ways. Our preference for a situated, relational conception of gender and culture derives partly from a quest for ecological validity but also from the implications that such conceptions carry for action and change, and for the responsibility they endow upon educational organizations for making change. We have a long history of equity research that has drawn conclusions about groups of people and publicized these, at some cost. In suggesting the idea that girls were lacking whether through genetic inferiority, ‘learned-helplessness’ or ‘maladaptive tendencies’ researchers also suggested that girls needed to change, diverting the focus from other places, such as the classroom environment, or subject, that may be more productively changed. Equity researchers, in particular, bear an enormous responsibility to consider the ways they are interpreting and framing their data, because of the ‘mythologies’ (Fennema, 1981, p384) of inadequacy that may be constructed. The prevailing notion that girls are innately inferior in mathematics is certainly a stumbling block in our efforts to provide girls with equal access to advanced mathematical fields. But such notions have a long societal history and have proved to be resilient. Michele Cohen (1999) gives an important historical perspective on the tendency of some people to consider women and girls as inherently inferior. She analyzed the recent furor in the UK that has been prompted by national examination data showing that girls are now ahead of boys in all subjects, including mathematics and science (DFES, 2004). In doing so she points out that female underachievement has always been partially accepted as a corollary of being female, whereas the idea of male underachievement has prompted recent, widespread investigations into the *external* culprits:

> Boys’ achievement has been attributed to something within – the nature of their intellect – but their failure has been attributed to something external – a pedagogy, methods, texts, teachers. The full significance of this becomes clear when the subject of the discourse is girls, for in their case it is their failure which is attributed to something within – usually the nature of their intellect – and their success to something external: methods, teachers or particular conditions. (M. Cohen, 1999, p20)

Varenne and McDermott (1999) advocate a refocusing of the equity lens away from individuals and categories of people, and onto the systems which co-produce difference. The re-focusing that they suggest involves departing from the essentialism of categories evident in claims that girls are 'maladaptive' or conceptually lacking, and committing to careful explorations of the circumstances that produce differences between groups. As with many such social constructs (e.g., race, ethnicity, class), gender has been used to order our world and categorically simplify it. Distinguishing masculine from feminine has, at times, served to propagate theories of inequality and inferiority rather than illuminate how context and practice create, indeed co-produce, gender inequality. In this chapter, the study of gender is taken up not as validation of a culturally produced hierarchical social order, but rather to challenge such ordering and question its place in an emerging tradition of educational research and practice. Under this rubric of research, gender is not a tool of essentialism (as it has been used in the past) but rather an analytical lens through which to understand *gender as response* and develop equitable educational practices and learning environments to reduce the inequities they produce. We have reached an important point in history, characterized by a wide-spread awareness of the need to make mathematics and science more equitable. We argue that an important part of the endeavor will involve displacing long-held myths concerning women's inferiority, and performing complex analyses of gender interactions in mathematics and beyond.

References.

Barnett, R., & Rivers, C. (2005). *Same Difference: How gender myths are hurting our relationships, our children and our jobs*. Basic Books: New York.

Becker, J. (1981). Differential Treatment of Females and Males in Mathematics Class. *Journal for Research in Mathematics Education, 12(1)*

Becker, J. (1995). Women's Ways of Knowing in Mathematics, in Rogers & Kaiser (Eds.) *Equity in Mathematics Education: Influences of Feminism and Culture,* London, Falmer Press, p.163-174.

Belenky, M.F., Clinchy, B.M., Golderberger, N.R, and Tarule, J.M. (1986). *Women's Ways of Knowing*. NY: Basic Books.

Benbow, C. P., & Stanley, J. C. (1980). Sex Differences in Mathematical Ability: Fact or Artifact? *Science, 210*, 1262-1264.

Boaler, J. (1997a). *Experiencing School Mathematics: Teaching Styles, Sex and Setting*. Buckingham: Open University Press.

Boaler, J. (1997b). When Even the Winners Are Losers: Evaluating the Experiences of 'Top Set' Students. *Journal of Curriculum Studies, 29*(2), 165-182.

Boaler, J. (2002a). *Experiencing School Mathematics: Traditional and Reform Approaches to Teaching and Their Impact on Student Learning.* (Revised and Expanded Edition ed.). Mahwah, NJ: Lawrence Erlbaum Association.

Boaler, J. (2002b). Paying the Price for "Sugar and Spice": Shifting the Analytical Lens in Equity Research. *Mathematical Thinking and Learning., 4*(2&3), 127-144.

Bombardieri, Marcella, (2005). ‘Summers' remarks on women draw fire’ January 17, 2005, *The Boston Globe*.

Bosch, C. & Trigueros, M. (1996). Gender and Mathematics in Mexico in Hanna, G. (Ed.). (1996). *Towards Gender Equity in Mathematics Education: An ICMI Study*. Dordrecht, The Netherlands: Kluwer Academic Press. pp 39-48.

Burton, L. (Ed.). (1990). *Gender and Mathematics: An International Perspective*. London: Cassell.

Burton, L. (1995). Moving towards a feminist epistemology of mathematics, in Rogers & Kaiser (Eds.) *Equity in Mathematics Education: Influences of Feminism and Culture,* London, Falmer Press, p.209-225.

Chipman, S. (1996). Female Participation in the Study of Mathematics: The US Situation. In G. Hanna (Ed.), *Towards Gender Equity in Mathematics Education: An ICMI Study*. Dordrecht, The Netherlands: Kluwer Academic Press.

Cohen, M. (1999). ‘A Habit of Healthy Idleness': Boys’ Underachievement in Historical Perspective. In D. Epstein, J. Elwood & V. Hey (Eds.), *Failing Boys? Issues in Gender and Achievement.* Buckingham, England: Open University Press.

Coley, R. (2001). *Differences in the gender gap: comparisons across racial/ethnic groups in education and work.* Policy Report of Educational Testing Service, Princeton, NJ.

DeBare, I. (2004). *Where Girls Come First: The Rise, Fall and Surprising Revival of Girls Schools*. Penguin: New York.

Department for Education and Skills (2004). GCSE and Equivalent Results for Young People in England, 2003/04 (Provisional). DFES: London.

Department for Education and Skills (2005). GCE/VCE A/AS Examination results for young people in England, 2003/04 (revised). DFES: London.

Dti (2005). Data on women's participation in mathematics and sciences. http://www.dti.gov.uk

Dweck, C. S. (1986). Motivational Processes Affecting Learning. *American Psychologist (Special Issue: Psychological science and education), 41*(10), 1040-1048.

Ethington, C. (1992). Gender Differences in a Psychological Model of Mathematics Achievement. *Journal for Research in Mathematics Education, 23(2)*

Epstein, C. F. (1988) *Deceptive Distinctions: Sex, gender and the social order*. The Russell Sage Foundation: New York.

Fennema, E. (1981). Women and Mathematics: Does Research Matter. *Journal for Research in Mathematics Education, 12*(5), 380-385.

Fennema, E., Wolleat, P., Pedro, J., & Becker, A. (1981). Increasing Women's Participation in Mathematics: An Intervention Study. *Journal for Research in Mathematics Education, 12(1), 107-113.*

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

Forbes, S. (1996). Curriculum and Assessment: Hitting Girls Twice? In Hanna, G. (Ed.). (1996). *Towards Gender Equity in Mathematics Education: An ICMI Study*. Dordrecht, The Netherlands: Kluwer Academic Press. pp 71-92

Gibson, J. J. (1986). *The Ecological Approach to Visual Perception*. Hillsdale NJ: Lawrence Erlbaum.

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

Greeno, J. G., & MMAP. (1998). The Situativity of Knowing, Learning and Research. *American Psychologist, 53*(1), 5-26.

Grevholm, B. (1996). Women's Participation in Mathematics Education in Sweden. in Hanna, G. (Ed.). (1996). *Towards Gender Equity in Mathematics Education: An ICMI Study*. Dordrecht, The Netherlands: Kluwer Academic Press. pp 111-124.

Hart, L. (1989). Classroom Processes, Sex of Student, and Confidence in Learning Mathematics*, Journal for Research in Mathematics Education*, 20(3).

Herzig, A. (2004a). Slaughtering This Beautiful Mathematics: Graduate Women Choosing and Leaving Mathematics. *Gender and Education, 16*(3).

Herzig, A. (2004b). Becoming Mathematicians: Women and Students of Color Choosing and Leaving Doctoral Mathematics. *Review of Educational Research,, 74*(2), 171-214.

Hyde, J. S., Fennema, E., & Lamon, S. (1990). Gender Differences in Mathematics Performance: A Meta-Analysis. *Psychological Bulletin*, 107(2), 139-155.

Jacobs, J., & Eccles, J. (1985). Gender Differences in Math Ability: The Impact of Media Reports on Parents. *Educational Researcher, March*, 20-25.

Johnston, B. (1995). Mathematics: an abstracted discourse, in Rogers & Kaiser (Eds.) *Equity in Mathematics Education: Influences of Feminism and Culture,* London, Falmer Press, p.226-234.

Koontz, T. (1997). Know thyself: the evolution of an intervention gender-equity program, in Trentacosta & Kenney (Eds.) *Multicultural and Gender Equity in the Mathematics*

Classroom: The Gift of Diversity 1997 Yearbook, United States, National Council of Teachers of Mathematics, Inc.

Leach, L. (1994). Sexism in the classroom: a self quiz for teachers, *Science Scope 17(6), pp54-59.*

Leder, G. (1982). Mathematics Achievement and Fear of Success. *Journal for Research in Mathematics Education, 13(2).124-135.*

Leder, G. (1996). Gender Equity: A Reappraisal. In Hanna, G. (Ed.). (1996). *Towards Gender Equity in Mathematics Education: An ICMI Study*. Dordrecht, The Netherlands: Kluwer Academic Press. pp 39-48.

Longino, H. (1987). Can There Be a Feminist Science? *Hypatia, 2*, 51-64.

Marjoram, T. (1994). Are/should boys and girls in mathematics be taught together?, *Gifted Education International*, 9(3), pp.152-3.

Mendick, H. (2005a). A Beautiful Myth? The gendering of being /doing 'good at maths'. *Gender and Education, 17(2).*

Mendick, H. (2005b). Mathematical stories: why do more boys than girls choose to study mathematics at AS-level in England? *British Journal of Sociology of Education*, 26(2).

Niederdrenk-Felgner, C. (1996). Gender and Mathematics Education: A German View. In Hanna, G. (Ed.). (1996). *Towards Gender Equity in Mathematics Education: An ICMI Study*. Dordrecht, The Netherlands: Kluwer Academic Press. pp 179-196

O'Hara, R. (2005). *Gender in Math, Science, and Engineering: Stanford Researchers Discuss New and Important Evidence*, February 4, Stanford University (http://www.stanford.edu/group/IRWG/NewsAndEvents/Forum.html)

Rosser, P. (1992). *The SAT Gender Gap: ETS Responds*. Report: Center for Women Policy Studies.

Ryan, J. (2005, March 3). Brains of Men and Women Only Part of Story in Science. *The San Francisco Chronicle,* pp. B-1.

Seegers, G. & Boekaerts, M. (1996). Gender-Related Differences in Self-Referenced Cognitions in Relation to Mathematics. *Journal for Research in Mathematics Education, 27(2)*

Spender, D. (1982). *Invisible Women: The Schooling Scandal*. London: Women's Press.

Statistical Research Center report (2003)*:* Physics Trends*. National Center for Education Statistics, Digest of Education Statistics.*

Spitaleri, R M (1996) Women's Know-How and Authority: Italian Women and Mathematics. In Hanna, G. (Ed.). (1996). *Towards Gender Equity in Mathematics Education: An ICMI Study*. Dordrecht, The Netherlands: Kluwer Academic Press. pp 205-214.

Varenne, H. and R. McDermott (1999). *Successful Failure: The School America Builds.* Boulder, Colorado: Westview Press.

Walden, R., & Walkerdine, V. (1985). *Girls and Mathematics: From Primary to Secondary Schooling*. London: University of London Institute of Education.

Walkerdine, V. (1989). *Counting Girls Out*. London, UK: Virago.

Witte, M. (1995). Constraints on Girls' Actions in Mathematics Education in Rogers & Kaiser (Eds.) *Equity in Mathematics Education: Influences of Feminism and Culture,* London, Falmer Press, 235-244.