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ABSTRACT

In this paper, emphasis is placed on examining the issue of sex differences from a historical perspective, within a framework focused on socialization factors, and within a more psychological framework that examines how society's beliefs and expectations are reflected in personal beliefs that may affect functioning. Biographical details about several female mathematicians are discussed first. Then research on parental factors that influence children's performance are reviewed, followed by a summary of school and teacher factors. How peer group values affect mathematics participation and achievement are next discussed. Finally, psychological explanations derived from research are presented. (MNS)

MODELS THAT EXPLAIN SEX-RELATED DIFFERENCES IN MATHEMATICS : AN OVERVIEW

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Despite the large amount of research on sex-related differences in mathematics achievement and participation, agreement has not been reached either on the extent of such differences nor on the relative importance of the factors contributing to them. Failure to distinguish between extension and replication studies has led to a number of contradictions. The diversity of research perspectives attracted to the field has also contributed to the lack of consensus. Nevertheless, it is convenient to carve the complex problem of sex differences into smaller, overlapping sections. In this paper emphasis is placed on examining the issue from a historical perspective, within a framework that views sex-related differences with an emphasis on socialization factors, and finally within a more psychological framework that examines how society's beliefs and expectations are reflected in personal beliefs that in turn may affect functioning.

MODELS THAT EXPLAIN SEX-RELATED DIFFERENCES IN MATHEMATICS : AN OVERVIEW

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Despite the large amount of research attention directed at the issue of sex differences in mathematics achievement and participation, agreement has not been reached either on the extent of such differences, nor on the relative importance of the factors contributing to them.

A careful reading of the relevant literature reveals an inconsistency of findings, with boys performing better in some studies and girls in others. Few consistent sex differences in performance in mathematics are found at the early primary school level. However, there is a substantial body of evidence to suggest that by the beginning of secondary schooling boys frequently seem to perform better than girls at mathematics. Differences in the samples being tested and the nature of the tasks to be performed make cross study comparisons difficult. Yet findings that have emerged in American studies with American samples are frequently replicated in other countries. Evidence of the poorer performance of girls, compared with boys, in public examinations and large scale testings can be inferred from English and Australian data (Cockcroft, 1982; Leder, 1980; Moss, 1982). The differences seem to increase as the level of examinations taken increases, and are particularly marked when above average performance is considered. These findings are noteworthy, since retention rates of students in mathematics courses in England and Australia tend to be higher than in the United States. In Australia, the majority of students take some form of mathematics till the end of year 10, while almost all girls, as well as boys, study mathematics up to the age of 16 in England and Wales (Shuard, 1982).

The emphasis in this paper on sex differences in no way implies a dismissal of the substantial amount of overlap between the sexes on a large number of dimensions. Within sex differences, i.e., individual variations among a large group of males or a large group of females, are far greater than consistent between sex differences.

A large number of factors are thought to contribute to sex differences in mathematics learning. For ease of discussion, these factors are frequently grouped into a number of coherent clusters. The fact that workers from a variety of disciplines have been attracted to the area, each intent on examining those aspects of the problem most congruent with their particular research perspective, has led to some fragmentation of the field. The ensuing tendency to concentrate on one or at best a small set of variables, and to ascribe differences obtained to these variables alone, has at times given rise to unproductive and largely artificial controversies, a consequence of the delineation of the problem rather than attributable to genuinely conflicting results. Yet a sensitive interpretation of the findings obtained, the ability to distinguish between extension and replication studies, together with a willingness to synthesize rather than polarize the results from investigations that have evolved from the different research perspectives can lead to a fuller and deeper understanding of the many facets that affect mathematics learning. Provided the constraints imposed by different disciplines are recognized, the diversity of approaches helps to describe the complex interaction of individuals with their environment more accurately.

In the research discussed in this session, emphasis is placed on cultural pressures and socialization processes. These are reflected in the expectations of parents, peers, school and society, and have led

to beliefs and prejudice about sex appropriate behaviour. The effect of these expectations on selected cognitive and affective variables is discussed in some detail by other participants in this session.

Before entering on a more detailed discussion of the influence of these social and cultural factors, it is fruitful to examine the question of sex differences in mathematics learning from a historical perspective. To borrow the sentiments expressed by Zeldin (1981,p.541), 'that ancient chimera, of using history to understand the present, takes on a quite different shape for me. I value history as a means of being made aware of my own prejudices, of developing a certain detachment'.

The scarcity of well-known, productive female mathematicians over the centuries has at times rather naively been used as an argument for a genetic contribution to the learning of mathematics. A careful appraisal of the relevant literature indicates that alternate interpretations are equally if not more plausible.

A historical survey of women in mathematics typically discusses the life and work of Hypatia, Emilie du Chatelet, Maria Agnesi, Caroline Herschel, Sophie Germain, Ada Lovelace (especially now computer usage has become so widespread), Mary Somerville, Sonya Kovalevsky and Emmy Noether. Typically, too, the interest shown and encouragement given by at least one close and important male are cited as essential ingredients for the realization of the mathematical potential of those female mathematicians. The fathers of Hypatia, Agnesi and Noether were mathematicians who fostered their daughter's interest in mathematics. The Marquise du Chatelet was encouraged in her mathematical pursuits 'by a family friend, M. de Mezieres, who recognized her genius' (Osen, 1974, p.53) and herself had the financial

means to buy high quality mathematical tuition. Much of the work for which Caroline Herschel is remembered was begun when she worked as an astronomical assistant to her brother William who appreciated her help sufficiently to write to the Queen of England in 1787, to ask that his sister be given an allowance of fifty or sixty pounds a year 'by way of encouraging a female astronomer .... She does it indeed so much better to my liking than any other person I could have, that I should be very sorry ever to lose her from the office' (Turner, 1977, p, 126).

Biographical description of the lives of these female mathematicians show another common theme. Because of prevailing conventions, mathematical studies had to take second place to more stereotyped or sex role appropriate activities. Emilie du Chatelet is described as an active participant in 'the social life of the court, especially the gambling and the amorous adventures' (Osen, 1974, p.54). Her prolonged affair with Voltaire provided the additional benefit of worthwhile intellectual stimulation, however. Maria Agnesi renounced the world of mathematics after her father's death and dedicated the last forty years of her life to charitable projects and in service to the poor, while Caroline Herschel's scientific endeavours were subservient to her brother's research. In a letter to a colleague Sonya Kovalevsky admits to her dual loyalties to mathematics and writing. 'All my life, I have been unable to decide for which I had the greater inclination, mathematics or literature. It is very possible that I should have accomplished more in either of these lines, if I had devoted myself exclusively to it; nevertheless, I cannot give up either of them completely (Osen, 1974, p.57).

The overriding influence of cultural pressures can be inferred from a number of other examples. Descriptions of educational programs for English women in the eighteenth century indicate that as well as singing, dancing, painting and needlework, they might be taught French, reading, writing and sufficient arithmetic for them to be able to keep household accounts. Evidence of the efficiency with which they carried out the latter task abound when historical records of stately homes in England are examined. Within the constraints imposed by society, women showed proficiency in quantitative skills. Further evidence is provided by the contents of a little known English periodical, the Ladies' Diary (Leder, 1981; Perl, 1979).

It is appropriate to turn now to an overview of socializing processes currently considered to contribute to sex differences in mathematics learning. For ease of review, they will be considered here under the headings of parental, school/teacher, and peer group influences. This approach of course is one of a number that could have been chosen, is not without overlap nor totally comprehensive.

Parental factors

Research indicates that parents influence their children's educational performance, including their performance in mathematics, in a number of ways. Representative of the findings are those of Husen (1967) who found that in the countries participating in his cross cultural study, student achievement in mathematics was related to parents' education and socio-economic status.

Generally, studies that examine the impact of the educational level attained by parents on their children's mathematics achievement (e.g., George and Denham, 1976; Lantz and Smith, 1981) mirror the

conclusions drawn by Keeves (1972) who found that 'in each analysis, characteristics of the home environment were found to make small but significant contributions to final achievement test scores (in mathematics)' (p.126).

A number of studies (Aiken, 1972; Alpert, Stelwagon and Becker, 1963; Armstrong and Price, 1982; Haven, 1972; Lantz and Smith, 1981) have found that students' attitudes towards mathematics and a decision to continue with mathematics were linked with their parents' conception of the educational goals of the school mathematics course, and with the extent of the mathematics education desired for their children by the parents. Other studies (e.g., Fennema and Sherman, 1977; Hilton and Berglund, 1974; Luchins and Luchins, 1980) have highlighted that parents are perceived as encouraging their sons' mathematical studies more strongly than those of their daughters.

The effects of parental factors should not be exaggerated. In isolation, their contribution to mathematics achievement is fairly small. Nevertheless, the consistency of the directions of the findings generally reported in the literature is compelling.

The relationship between the home environment, as described by parents' level of education, occupation, and attitude towards mathematics is merely a subset of the broader area of interactions between parents and their children. There is abundant evidence that parents frequently behave differently towards and have different expectations for their sons and daughters. They tend not only to encourage their children to develop sex-typed interests, but even to discourage their children, and particularly their sons from participating in activities they considered more appropriate for the opposite sex. Substantial differences between the

spontaneous play of boys and girls are evident by the time they enter nursery school (Eynard and Walkerdine, Maccoby and Jacklin, 1975). Not only are these differences frequently reinforced by parents, but many are also the result of imitating the behaviour of others. Many parents still see their sons' and daughters' long term roles, and hence their need for education, as being different. Anecdotal illustrations of such views abound.

The long term effects of sex differences in childhood experiences on factors important in the learning of mathematics are far reaching. The review of socialization processes is continued by examining the influence of school and teachers on student performance, particularly in mathematics.

School and teacher factors

There are a number of ways in which schools, and teachers within the schools, differentiate between students on the basis of sex. The former do so through their organizational procedures, the latter through their behaviour, expectations, and beliefs.

In countries where sex segregated education is still reasonably prevalent, it is frequently viewed as an anachronism that reflects the now outmoded beliefs that the two sexes have different educational needs. Instead, co-education is cited as the avenue through which similarity of treatment of the sexes is achieved. This assertion is examined in more detail later. The question of segregated education is discussed first.

Single sex schools provide a clear illustration of sex linked divisions in education. The degree to which a community provides for education in single sex schools is an explicit measure of the extent to

which it considers that boys and girls require different preparations for different adult roles. Currently, opinion seems somewhat divided about the effect on girls of education in such an environment. Some (Cockcroft, 1982; Harding, 1981; Ormerod, 1981) have argued that girls studying maths and science seem to be disadvantaged in a mixed school setting. Others (e.g., Dale, 1974) reported that girls in co-educational schools performed better in mathematics than those in single sex schools. Care must be taken when subject preferences and performance are compared across different school systems in which equipment available, staffing and class sizes may not be comparable. In both England and Australia where a section of the school population is still educated in single sex schools (though in both countries there is an increasing trend towards coeducation for economic as well as educational considerations), many of these schools cater for children from higher socio-economic homes. The effect of parents' education and occupation on their children's mathematics learning has already been referred to. Studies which have examined the apparent benefits or disadvantages of education in a sex segregated environment have paid insufficient attention to those confounding factors.

It is worth emphasizing that there is a substantial amount of research evidence that coeducation does not signify equality of policy and practice between the sexes (Casserly, 1980; Ernst, 1975; Fennema and Sherman, 1977; 1978; Fennema, Wolleat, Pedro and Becker, 1981; Haven, 1972; Luchins and Luchins, 1980). When boys and girls study the same subject from the same textbooks there are often implied differences in their relevance for male and female students. Modern textbooks and tests have been written in ways that minimize sex role

stereotyping. Yet such stereotyping is still prevalent in fiction book characters, in older textbooks to be found on library shelves, and in the ways some teachers communicate with their students.

Teachers, it has been shown (Becker, 1981; Dweck; Davidson, Nelson and Enna, 1978; Samuel, 1981; Serbin; O'Leary, Kent and Tonick, 1973; Stallings, 1979) may react differently to their male and female students. They are likely to entertain the perceptions and attitudes towards sex roles that are prevalent in the society of which they are a part. Thus they are likely to contribute to the maintenance of sex role delineations.

The third major component of socialization processes to be considered is that of the peer group.

Peer group values

The peer group acts as an important reference for childhood and adolescent socialization and further perpetuates sex role differentiation through sex typed leisure activities, subject preferences and career intentions.

The preference of boys for more active games and pastimes concerned with skills and mastery of objects, and of girls to use play to practice skills related to mastery over people and inter-personal relations is frequently documented, and conforms with common adult expectations as well. It has also been argued (e.g., Stein and Bailey, 1975) that females and males differ in the areas in which they strive for achievement. While males tend to aim for achievement in the traditionally highly valued areas of intellectual expertise and leadership skills, females, they suggest, are more likely to strive for excellence in areas

more congruent with their traditional role, i.e., areas that require social skills. Yet Simkin (1979) showed that sex differences in valuations of success may vary depending on the instruments used to study them.

The sex differences in leisure time activities and particularly in attitudes towards mathematics (Fennema and Sherman, 1977; 1978; Fox, 1977; Fox, Pasternak and Peiser, 1976; Keeves, 1973; Hilton and Berglund, 1974; Preece and Sturgeon, 1980; Sherman, 1980) are reflected in the career expectations of males and females. The occupational intentions of boys and girls imply that competence in mathematics is a more important prerequisite for the attainment of the career ambitions of the former than the latter. In some studies, (Pedro, Wolleat, Fennema and Becker, 1981; Wolleat et al, 1980) this view is expressed explicitly by boys and girls. The long term effects of early career expectations on decisions to opt out of mathematics courses are substantial.

The persistence of the low participation rates of women in mathematics and mathematics related careers should be noted. Rossi (1972) showed that in selected professions, the increase in the absolute number of women attracted to them was dwarfed by the much greater increase in the number of men. 'The field of mathematics is a good illustration of this : there has been a 210 per cent increase in the number of women, but the number of men in mathematics increased 428 per cent, with the result that the percentage of mathematicians who are woman actually declined from 38 in 1950 to 26 per cent in 1960 (pp.72-73). Relevant data for England have been presented by Kelly (1974), while Keeves and Read (1974) pointed out that in Australia

in professions such as architect, engineer, scientist, doctor and dentist - there were proportionally fewer women in 1971 than in 1911 and 1921.

The review of peer group factors has revealed consistent differences between boys and girls in terms of leisure time activities and career intentions. These sex related differences in behaviour and expectations are at the same time self perpetuating and self promoting. Their relevance to aspects of mathematics learning has been stressed. The pervasiveness of the socialization process reviewed under the umbrella of peer group values, as well as those reviewed in the earlier sections, is highlighted by the finding from the IEA study that, while boys performed better than girls within each country included in the survey, girls in some countries performed better than boys in others.

It is, however, unsatisfactory to explain sex differences in mathematics learning through socialization processes along. The inadequacy of such an approach is highlighted by the example given by Maccoby and Jacklin (1974) of the four year old girls whose own mother was a doctor yet who insisted that only boys could become doctors, that girls should become nurses. As pointed out by Kelly (1981), socialization theories with their emphasis on reinforcement and imitation of the behaviour of others fail to explain this inconsistency. An appeal to psychological explanations is more fruitful. It should be stressed that this approach is here considered to be supplementary rather than contradictory to attempts to invoke socialization processes to explain sex differences. How society's standards, beliefs and expectations are reflected in personal beliefs that in turn may affect functioning is examined next.

Psychological explanations

The most persistent and pervasive finding that emerged from the Fennema and Sherman (1977, 1978) study, mentioned earlier, with students from grades 6 to 12 was that boys consistently showed greater self confidence than girls in their ability to learn mathematics. These differences in confidence about mathematics were not paralleled initially by differences in achievement. However, for the older students there was a high correlation between mathematics performance and confidence in mathematics score. The latter predicted subsequent performance in mathematics for girls, but not for boys. Other researchers have also found that girls under-estimate their level of performance more frequently than boys. Representative are the results of Beswick (1975) who found, in a study involving more than 4500 grade 12 students, that girls underestimated the end of the year grades in their best three subjects by about the same margin with which their average performance in fact exceeded that of the boys. Almost twice as many boys as girls considered themselves capable of further mathematical studies. Other relevant research findings have come from studies concerned with the motive to avoid success, or the fear of success (FS) construct.

Attempts by McClelland and his co-workers (McClelland, Atkinson, Clark and Lowell, 1953) to validate their achievement motivation construct gave rise to sex-linked conflicting findings. Cues that stressed leadership and intelligence qualities aroused optimal achievement efforts in males but did not necessarily affect females in the same way. Instead, the latter frequently responded more positively to situations that concerned approval and affection from others. Since achievement motivation was 'assumed to be a multiplicative function of the strength of the motive, the expectancy (subjective probability) that the act will

have as a consequence the attainment of that incentive, and the value of the incentive' (Atkinson and Feather, 1966, p.13), presumably sex differences in expectations of reaching the incentive and/or valuation of that incentive helped to account for the differences in achievement arousal. In postulating the motive to avoid success, Horner (1968) argued that for many females attainment of success, particularly in areas considered by society as being less appropriate for females, produced anxiety. This anxiety was likely to have an adverse effect on performance. Put slightly differently, fear about the consequences that might follow the attainment of success interfered with maximum performance. While FS was postulated to be more prevalent in females than in males, it was not expected to be equally important for all women. FS should be more characteristic of high ability, high achievements-oriented females who aspired to and were capable of achieving success, than of low ability, low achievement-oriented females who neither desired nor were capable of attaining success. FS should be aroused particularly when the tasks involved were generally 'considered masculine such as tasks of mathematical, logical, spatial, etc., ability' (Horner, 1968, p.24). An unwillingness to pay the price extracted from those who conspicuously contravene cultural norms may help to explain the lower performance of post primary school girls, compared with boys, in mathematics, as well as the consistency of the findings that boys are over-represented among the top mathematics performers.

Horner's theoretical construct aroused much interest and has continued to generate a considerable amount of research activity. Because of the large number of variables linked in different studies with FS, as well as the variety of instruments used to measure FS,

cross study comparisons need to be made with care. Nevertheless, as predicted implicitly by Horner, both males and females typically expressed more negative imagery in response to a cue depicting a successful female figure than to one with a successful male figure. Greater FS was aroused by cues that described success in a field likely to be sex role deviant for the figure depicted than by cues that depicted success in traditional spheres. Conflict, as described and quantified by the FS construct and experienced by successful females should be seen in tandem with the lower expectations of performance in mathematics expressed by girls, expectations that in time became self fulfilling (Fennema and Sherman, 1977; 1978).

Sex differences in achievement motivation have also been linked with sex differences in attributions of success and failure. The few studies that have concentrated on success and failure attributions in a mathematics setting (Gitelson, Petersen and Tobin-Richards, 1982; Leder, 1982; Wolleat et al, 1980; Pedro et al, 1981) have reported less functional attributions of success and failure in mathematics by girls compared with boys. While the effect size of attributional patterns on performance in mathematics may be small, the consistency of findings in this area indicate that sex differences in attributions may provide another useful piece in the jigsaw of factors that contribute to sex differences in mathematics learning.

How factors like the ones discussed in this paper can be organized constructively to increase our understanding of sex differences in mathematics learning is taken up in the remainder of this section.

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