Sex Differences in Mathematical Performance: What do we know about them?

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It is generally accepted that mathematics is one academic field where male superiority of achievement is well-established. Far fewer women than men go into careers as mathematicians[1] and those who do, generally do not reach equal employment status with men. Such facts seem to be the culmination of sex differences in mathematical performance which begin to appear around the age of 12 to 15.[2] Up till then, the mathematical performance of boys and girls seems to be fairly equal at any of the three cognitive levels of computation, knowledge of concepts and problem-solving ability on which mathematical achievement is most commonly gauged. The change in performance at the secondary level of schooling tends to be in favour of males who are seen to perform better than females particularly on tasks involving visual spatialisation ability and mathematical reasoning. The girls' discontinuity of performance, even when they have had an identical learning background, has prompted researchers to investigate possible explanations for a phenomenon which *Walden and Walkerdine* (1982)[3] stress should not be confused with an "overall failure."

Suggested Explanations for Observed Differences

These tend to emphasise either

(i) biological/innate differences between the sexes as (hypothetically) resulting in differential cognitive abilities and hence differential mathematical performance, or

(ii) the effect of attitudes and expectations on actual performance, as well as the influence of factors of sex-role socialisation and other environmental conditions on the development of such attitudes.

It will be apparent that the different emphasis echoes the old Nature/Nurture controversy dominant in many areas of Developmental Psychology. Clearly, however, Nature cannot show without some Nurture, while Nurture is in most cases modified by Nature. Thus, the above distinction between explanations reported in this paper is only adopted as a convenient organisational devise. The complexity of the interrelationship between influential variables becomes apparent in the findings of various studies some of which are considered in this paper.

Some "Biologically-based" Explanations

The investigation of innate or genetic characteristics as potential determinants of sex differences in mathematical performance is often justified through reference to statistical data which show a greater frequency of male geniuses in the field of mathematics. It is also argued that since outstanding mathematical performance appears very early, such a performance is more likely to have a genetic component in either sex than to appear solely as a result of socialisation.[4] A further reason for looking at innate characteristics as potential sources (among others) of differential mathematical performance has been the controversial finding that sex differences in mathematical achievement persist even when differential course-taking is controlled for. The dimension on which such genetic differences are hypothesised to occur is the cognitive one whose development, perhaps because of Piaget's mathematical model of thinking, has come to be seen as occurring parallel to the development of mathematical ability. Along this dimension, sex differences in spatial visualisation ability as well as in basic logical skills have been hypothesised as accounting for many of the differences in mathematical achievement, particularly in geometry where the ability to perceive relations in space and visualise objects in three dimensions is seen to be essential.[5]

Spatial Visualisation Ability and Mathematical Achievement

At least three theories which stress the biological basis of visual-spatial ability have been proposed.

The first is known as the "X-chromosome theory". Briefly put, this theory holds that a recessive gene giving visualisation ability is carried on the X-chromosome. The claim is that males, who only possess one x-chromosome, inevitably exhibit the visualisation trait whenever the gene is present. In females, however, who carry two X-chromosomes, the gene would have to appear on both in order to be expressed. The greater probability of males' possessing the relevent gene is held to be responsible for their superior spatial visualisation abilities. A serious criticism of this theory has been made by *Archer and Lloyd* (1982)[6] who point out that the theory rests on the assumption that such genes which influence intellectual development actually exist: evidence from cross-cultural studies of families have failed to produce the predicted pattern of within-family correlations in intellectual functioning. Despite such evidence, the notion that sex-differentiated spatial abilities are genetically-based still persists.[7]

A second genetic theory is the Brain Lateralisation theory which attributes higher spatial ability in males to observed different patterns of hemispheric localisation of mental ability functioning in males and females. Disagreement over the precise link between hemispheric differences and specific mental abilities,[6] however, leaves the claim still open to question.

Sex hormones have also been hypothesised as acting on the brain to produce differences in spatial and other abilities. But, as *Archer and Lloyd*[6] point out, evidence in support of this explanation is again weak. Besides, like the two preceding it, the explanation is inadequate in that it does not consider any possible interaction with the environment in the expression of the traits. Such interaction should certainly be taken into consideration particularly when one remembers that even in more clearly understood genetic traits like diabetes, the influence of environmental conditions may be seen to affect the nature of, and extent to which, the predisposition develops.

It is clear that considerable uncertainty continues to surround the acceptability of biologically-based theories as providing an adequate explanation for differences in spatial visualisation ability. Furthermore, *Fennema* (1980)[5] reports that "although the relation between the content of mathematical and spatial visualisation skills appears logical, results from empirical studies that have explored the relationship are not consistent".

Given this lack of conclusive empirical data on the very existence of a relationship between spatial visualisation and mathematical learning, it appears even more unlikely that any relationship between visual spatialisation and different mathematical performance between the sexes could be readily determined. Thus, while the hypothesis seems reasonable in the light of numerous studies which report sex differences on either dimension as beginning to appear at roughly the same time,[2] studies conducted with the specific intention of investigating the relationship between visual spatialisation skills and mathematical ability have failed to provide supporting evidence for this hypothesis. In a study of grade 6 to 12 students (ages 12-18 years), *Fennema and Sherman* (1977)[8] found, for example, that while a positive relationship existed between visual-spatialisation skills and mathematical achievement, this was not differentiated by sex. A later study by *Sherman* (1980)[9] also reports sex differences in visual-spatialisation ability to have developed from grade 8 to grade 11 (ages 14—17 years) so that sex-related differences found in mathematical achievement by grade 11 (age 17 years) are attributed to the effect of sex-role socio-cultural influences.

In conclusion, it might therefore be said that although there are various indications that a relationship exists between visual-spatialisation abilities and mathematical performance, the nature of this relationship is still unclear. Furthermore, although various genetic theories have suggested explanations for this relationship, no claim may be made that biological factors are to be held wholly responsible for differences in mathematical performance. This, however, does not rule out the possibility of a genetic component in mathematical ability which is indicated by studies reporting the early appearance of outstanding mathematical ability among children of both sexes. Finally, variations in visual spatialisation do not fully accunt for those differences in mathematical achievement which are sex-related.

Basic Logical Skills and Mathematical Performance

A different level of cognitive functioning hypothesised to be related to sex-differences in mathematical achievement is logical thinking. As indicated earlier, mathematical achievement is seen to depend on the development of computational skill, knowledge of concepts and problem-solving ability. The three conditions are seen as necessarily following one upon the other so that although the conceptual nature of mathematics is present even during the teaching of initial computational skills, conceptual aspects are emphasised in the higher level mathematical courses of algebra, geometry, trigonometry and calculus typically found during the secondary school years. A Piagetian perspective would see this greater emphasis as coinciding with the period when the transition from the concrete to formal operational thought is expected to occur. It is alsc, of course, the perod when sex-related differences in mathematical achievement have been reported to occur so that it has been hypothesised[10] that sex-related differences in mathematical achievement may be a function of later attainment of the formal operational stage by females. *Kaplan and Plake*[10] state, however, that empirical assessments of formal operations by various researchers suggest that this might not be an adequate explanation. They themselves, in a study which investigated the relationship between level of cognitive development and mathematical achievement for college students of both sexes, found that logical skills measured on a Test of formal operations existed equally in females as in males but without being accompanied by a high level of mathematical achievement. It is therefore suggested that formal operation skills must have developed in females through interaction with non-mathematical problems and materials so that they call for remediation programmes which would attempt to generalise these skills to the mathematics domain. Piaget's (1972)[11] proposal that one is more likely to demonstrate higher level skills in the area of one's special interests is used to support their suggestion that mathematical skills may first be built up in the individual's particular area of high interest and later transferred to the area of mathematics.

The implication of this last suggestion is that mathematical achievement may well be influenced by factors which do not derive solely from within the individual but may also be a function of environmental influences. Various researchers have identified a wide range of such factors some of which are discussed in the following sections.

The Role of Environmental Factors in Mathematical Performance

Environmental factors hypothesised to affect sex-related differences in mathematical performance may generally be seen to be related to sex-role socialisation and to derive from the two major formative influences in the young child's life: the school and the home.

Schooling

Differential treatment of boys and girls by the teacher, as for example, in implicitly or explicitly communicating different behavioural expectations from boys and girls (in terms of such things as neatness in work, level of noise tolerated, play activities engaged in, etc.) are seen to perpetuate stereotypical expectations present in society which, among other things, looks on mathematical activity as being a masculine, rather than a feminine or neutral one.[12]

Such expectations, when communicated by such "significant others" as teachers, are held to have an important effect on the child's developing attitudes towards the subject. The conviction that attitudes affect achievement has been behind much of the work done on attitudes towards mathematics itself and on the relationships between self-concept of ability and achievement in mathematics.[13]

Affective factors such as attitudes are reported not only to affect the "amount of effort one is willing to exert to learn mathematics but also (to have) great influence on the election of mathematics courses beyond minimum requirements". *Sherman* (1980)[9] for example, found that although changes in visual-spatialisation ability among girls tested from grade 8 to grade 11 (ages 14 to 17 years) did not occur, attitudes towards learning mathematics were seen to become less favourable and performance to decline.

The hypothesis that attitudes and beliefs are related to achievement in mathematics appears to be consistently supported by research findings. This does not, however, imply that a casual relationship between the two variables may be claimed. Further studies are required in order that this kind of relationship might be demonstrated.

The effect of teacher behaviour on sex-differentiated performance in mathematics has also been extensively discussed. In the report of an observational study of mathematical learning in infant schools carried out by *Walden and Walkerdine* (1982)[3] over a two-year period, the researchers observe that mathematics is frequently referred to as "hard work", "a job", so that they suggest that pupils' perceptions of mathematics might well be prejudiced by the teacher's own feelings about the subject as implicitly communicated through the use of such language. The authors argue that these feelings often derive from the teachers'(generally female) insecurity in their own mathematical ability which at the same time recognises the subject as highly important in society. This compound of attitudes is held to lead to a determination to teach the subject "properly" calling for a greater display of class control lest attempts at re-explaining might result in the creation of further confusion in the pupils' understanding. The further idea that teachers are more likely to focus on the boys in their attepts to keep their class under control is also sometimes held to contribute to the establishment of mathematics as a male domain subject. This idea is supported by *Fennema* (1979)[14] who argues that, being seen as potentially more disruptive, boys become more salient in the teacher's frame of reference and consequently receive more attention, in terms of both praise and blame, than girls. Looking at the mathematical performance of boys and girls, *Fennema* later concludes that "differential standards for mathematical achievement are communicated to boys and girls through differential treatment as well as differential expectations of success". She therefore interprets the teacher's concern with maintaining authority in the class as possibly mediating sex differences in mathematical achievement.

Contradictory findings to these are reported by *Parsons et al* (1982)[13] whose study of classroom influences of children's achievement reports no evidence of sex-discriminatory use of praise and criticism by teachers. *Walden and Walkerdine*'s[3] observations are in agreement with this view. They claim that their observations revealed that in the nursery and primary schools they visited, teachers chose to reinforce or correct behavioural traits regardless of the sex of the child who exhibited them. *Parsons et al*'s[13] study however, does lend support to the view that teacher behaviour influences pupils' attitudes: sex differences were found in the relationship between teachers' use of praise and criticism and pupils' self-concept of ability and expectancies in mathematics. Thus, high levels of teacher praise and criticism were found to be good predictors of self-concepts of ability for boys but not for girls. The authors, however, point out that the frequency rates of the use of praise and criticism were quite low so that this, coupled with the finding that praise and criticism were not so predictive of students' self- and task-concepts as other measured variables (e.g. students' past performance and teachers' expectancies) indicates that students' self-concepts must be mediated by more subtle processes than the variables of teacher-student interaction observed in their study.

Other school-based variables which have been investigated as relevant to the topic being discussed relate to school organisation. A modern, as opposed to a traditional orientation, for example, is held to affect pupil performance in mathematics with traditional schools producing greater sex differences in behaviour, including performance on intellectual tasks such as problem-solving and coding tasks.[15] Having single-sex as opposed to mixed-sex schools has also been found to be related to performance in mathematics by *Husèn* (1967)[16] in a study in which he compared data from twelve countries. More recent cross-cultural studies do not support this.

Evidence also exists that differences in amount of time spent studying mathematics may also account for some of the sex differences found in mathematical performance. This view is strongly held by *Fennema* (1980)[5] who claims that when amount of course-taking is controlled for, few sex-related differences in achievement are found. Fennema's argument, however, loses most of its strength outside an American context where the situation differs from the British, and indeed the Maltese one, in that American children may opt to stop studying mathematics completely. In Britain, on the other hand, mathematics remains compulsory till school-leaving age so that children of both sexes spend the same amount of time in studying mathematics till that age. It is clear, therefore, that sex differences in mathematical achievement found in British data cannot be interpreted as being a function of different amounts of mathematical study as readily as American data might. Studies which show improvement in mathematical skills following training in specific areas[7] indicate that the hypothesis is a useful one.

The Home Environment

The role of the home in the development of sex-related differences in mathematical achievement may also be described in terms of sex-role socialisation. Parents are perhaps the most influential role-models in the child's experience so that it is suggested that mathematical performance may be influenced by children's perception of the usefulness of mathematics in the life of their parents. As the structure of our society makes it more likely to be the father rather than the mother who is engaged in activities requiring formal mathematical abilities, it is hypothesised that boys are more likely to perceive mathematics as being useful to their future role and hence aspire to achieve in it. Girls are similarly likely to see mathematics as a male domain subject, yet, since they identify more with their mother, their perception of mathematics is expected to result in the syndrome called the "fear of success". In this situation, the daughter is described as perceiving a conflict in her sex-role which in turn inhibits mathematical achievement. *Sherman* (1980)[9] supports this argument. An earlier study which she conducted together with *Smith* (1967)[17] in the performance of 12/13 year old orphaned girls as compared to girls from "normal" families also indicates support for the parental modelling hypothesis.

In contrast, *Parsons et al* (1982)[13] who also studied parental influences on the development of achievement attitudes as measured on mathematical tests given to 11 to 17 year-old-students, found that parents do not influence their child's achievement attitudes through their power as role models. Rather, parents were found to be influential in the formation of children's achievement attitudes through communicating their expectations regarding their children's abilities. As hypothesised, the study found that parents held sex-differentiated perceptions of their children's mathematical abilities even when the actual performance of boys and girls were similar.

Parents of daughters expected their child to need to work harder at mathematics in order to do well, than did parents of sons. These stereotypical views among the parents were then reflected in the children's own perception of their parents' beliefs and in their own self- and task-perceptions. Indeed, parents' beliefs were found to be more directly related to children's self-concept of ability and expectancies than to their past performance. Therefore, since parental beliefs were so highly sex-stereotyped, as well as so strongly related to pupils' self- and task-perceptions, it may be inferred that parents could easily be responsible for handicapping girls with lower expectancies for mathematical achievement, and ultimately, career aspirations. Lack of longitudinal data which tests the long-term effects of the reported relationship leaves the question open to investigation.

Conclusion

The above discussion will have made it clear that the importance of the sex-role stereotyping which occurs in both school and home cannot be underestimated. Studies reviewed in this paper have consistently reported finding relationships between socially-mediated attitudes and achievement in mathematics. Yet, despite the wealth of data which links environmentally-derived factors with sex differences in mathematical achievement, no causal relationships have yet been identified or proven to exist between the two variables. In this respect, it may be seen that the situation echoes that holding for factors which are assumed to have a genetic origin: are the variables simply "related", or does one cause the other? Or is it indeed that they are more intricately interrelated and involved in a complexity of cause and effect as well as other relationships?

No clear answers appear possible. As stated at the beginning of this paper, the interplay between factors is a complex and often subtle one. Studies can isolate only a handful of variables at any one time and indications for further research made by any particular researcher are not always followed up. Thus, the overriding impression that one is left with is that work in this field is still at an exploratory stage and requires both imaginative as well as rigorous research before an answer to the question heading this paper may be more conclusively given.

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