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ABSTRACT

This collection of papers resulted from the observation that girls, before boys, are eased out of science education. An overview of the problem is presented in the first paper, with an identification of some of the factors that discourage girls from pursuing study or careers in science. Justification for teaching science to girls as well as to boys is the central point of the second paper. Sex difference in ability is extensively covered in the third paper. Included is a review of the literature on sex differences, the relevance of these differences to success in science, and evidence relating to the development of these differences. The author of the fourth paper reports results that show polarization in attitudes to school subjects between the sexes. It is reported that girls in single-sex schools study more physical science than in co-educational schools. Reasons for this difference are explored. The final report makes recommendations regarding the disadvantages a girl experiences in studying science. (CS)

GIRLS AND SCIENCE EDUCATION - CAUSE FOR CONCERN?

Centre for Sc[illegible]nce Education,
Bridges Place
London S.W.6 4[illegible]R.

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Introduction

Most would agree that the struggle to establish a place for science in the school curriculum had been successful by the nineteen sixties, but in the seventies it is apparent that physical science continues to be limited in the education of girls. Why should this be and should it give cause for concern?

A Conference held in March, 1975, at the Centre for Science Education, Chelsea College, considered these questions and the following collection of papers provides a report of that conference.

In the first paper Alison Kelly uses statistics to demonstrate how girls are eased out of science as their education develops and suggests some factors that may be responsible.

Roy Schofield considers the questions "Why teach science" and "What science shall we teach?", presenting alternative answers and their implications for the education of girls.

The possibility that abilities, significant for the learning of science, differ between the sexes, is examined in the paper by Esther Saraga, in which she reviews research evidence and sounds a note of caution about some assumptions derived from it.

Milton Ormerod reports on some results of his recent research show marked polarisation in attitudes to school subjects between the sexes, particularly in mixed schools, where physics is very unpopular with girls.

In the last paper an attempt is made to sum up the discussion that took place during the conference; it examines the dimensions of the problem and points to the changes that may have to be made to effect some modification of girls' non-involvement with the physical sciences.

A DISCOURAGING PROCESS: HOW WOMEN ARE EASED OUT OF SCIENCE

Alison Kelly,
Research Fellow,
Centre for Educational Sociology,
Edinburgh University.

A Discouraging Process: How Women Are Eased out of Science.

This paper presents an overview of the position of women in science both at school and university and in their later careers. It attempts to identify some of the factors which discourage girls from pursuing study or careers in science. These factors fall into three main groups - sociological, psychological and educational. The educational determinants within the school system are relatively accessible and amenable to change, and these will be only briefly considered. My main purpose is to set the scene by concentrating on sociological and psychological influences outside the educational system. These influences are not, in general, fixed or immutable; but they are more difficult to alter than within-school factors, and (for the time being at least) science educators must accept that they exist and work within the framework they define.

First, let us be clear about the scale of the problem. Table 1, taken from Statistics of Education 1972, compares the numbers of girls and boys attempting CSE and O level science examinations. The numbers are expressed as a percentage of the number of school candidates at CSE or O level, and so represent an estimate of the proportion of pupils who study science in the ability ranges covered by these examinations.* Unfortunately it is not possible from official publications to get information on science study referring to younger or less able pupils.

The differences between boys' and girls' patterns of examination attempts is striking. A high proportion of boys take physics and technical drawing at CSE - possibly in preparation for apprenticeships. The less vocational sciences - chemistry, biology and general science - are less common with CSE boys. However girls frequently take biology at CSE, but seldom attempt physics, chemistry or general science. The situation is similar amongst the more able pupils who take O levels, although the contrasts between boys and girls - indicated by the ratios in the last column of Table 1 - are less pronounced. Only about 15 per cent of the girls in this group attempt physics or chemistry, compared with nearly 50 per cent who attempt biology. However physics and chemistry are common for boys, with biology taken less often.

Thus in any discussion of girls' participation in science and their attitudes towards it, biological and physical sciences must be clearly distinguished. Whereas a large proportion of girls in the ability ranges covered by CSE and O level

* This estimate is slightly inaccurate because (1) candidates from outside school are included in the number of attempts for each subject, so exaggerating the proportions and (2) the tables are not exclusive since some candidates attempt both O level and CSE examinations, so depressing the proportions.

are studying biology at least until they are sixteen, this is not true of the physical sciences. There may be criticisms of the content and methods of biology courses, but at least biology is reaching girls - perhaps it is boys that biologists should be worrying about! For this reason most of what follows will apply chiefly to the physical sciences. At present O levels are taken by the top 30 per cent of sixteen year olds. Yet only 15 per cent of the girls in this ability range attempt physics and chemistry. So approximately 85 per cent of the most able girls (and an even higher percentage of the less able) are leaving school with a minimal knowledge of the physical sciences.

Table 1

The percentage of all male and female school candidates at CSE and O level who attempt science subjects. (Data from Statistics of Education, 1972, Volume 2, Tables 25,27 and 29.)

	Boys	Girls	Number of boys for every girl
	%	%	%
CSE			
Biology	14.9	33.7	0.5
Mathematics	72.6	66.3	1.1
General Science	11.5	5.6	2.1
Chemistry+	20.5	8.0	2.6
Physics+	42.6	5.6	7.9
Technical Drawing	37.8	0.4	88.6
O Level			
Biology	25.9	49.1	0.6
Mathematics	59.9	42.7	1.5
Chemistry+	30.5	15.6	2.1
Physics+	42.3	13.7	3.4
Technical Drawing	18.5	0.3	63.9

+ Candidates attempting physics with chemistry have been included in both chemistry and physics figures, so as to give the proportion of candidates who attempt any chemistry and any physics. Approximately 3 per cent of candidates attempt physics with chemistry.

I do not intend to argue at length the case for extending the teaching of science to more girls, but a few words are in order. Leaving aside the sheer stimulation and enjoyment of science (which is sometimes difficult to transmit), science must be seen as an integral part of general education. We live in a technological society, and if education aims to equip girls to live in this society it is ludicrous that science is so often absent. Quite apart from the practical skills such as wiring plugs and putting up shelves, a scientific education implies replacing superstition and blind fate with the ability to understand and control one's environment. If people feel bewildered or threatened by technology they cannot be blamed for turning away from rationality; but society's problems will not be solved by such a turning away. Thus a basic grounding in science for the non-specialist becomes ever more essential. A different, but equally important, argument concerns the present waste of scientific talent amongst girls, a waste which is clearly illustrated by comparing women's contribution to science in this country and abroad. These two aspects of science education - as part of a general education for the non-specialist, and as training for the future scientist - must be clearly distinguished.

Having shown that, by O level, girls are grossly under-represented in physical science, I now want to consider what produces this situation. I shall follow a developmental sequence, showing how the discouragements pile up from birth to sixteen. Beyond sixteen the discouragements continue, affecting women who might become career scientists.

Are girls born with an innate handicap in science? It seems possible that they are. Apart from general intelligence, the only specific ability which has been closely linked with science attainment is spatial ability - that is the ability to manipulate two or three dimensional shapes or objects mentally. From an early age boys do better than girls on this type of test, and there is some evidence that the ability is genetically and hormonally linked to masculinity. Correlation studies between parents and children suggest that spatial ability is at least partially controlled by a recessive gene carried on the X chromosome (i.e. sex-linked). And studies of West African males hormonally feminized by kwashiorkor show that although their general ability is not altered, their spatial ability is below average. (For further details see Buffery and Gray (1972) who give a detailed discussion of the biological basis for sex differences in spatial ability.) It is difficult to see how environmental influences could produce these results - although doubtless sex differences in spatial ability are exaggerated by boys' greater tendency to play with mechanical toys. But we must be careful not to over-estimate the importance of spatial ability. Individual differences are always greater than group differences, and many girls will have greater spatial ability than many boys. Above all ability differences must be seen as a challenge to devise courses which take advantage of girls' talents, not as providing an excuse for not teaching science to girls. In other countries, notably the Soviet Union where 30 per cent of engineers and 70 per cent of doctors are female, large numbers of women study science successfully in spite of any sex differences in spatial ability.

Other specific abilities have not been linked so closely to science attainment, or indeed to biological factors. Perhaps surprisingly, mathematical ability (at which boys again perform better than girls) does not seem to have great bearing on science. Creativity tests give inconsistent sex differences, and bear little relationship to science performance. Girls do better than boys on verbal tests and manual dexterity tests, but again the relation with science is small.

It is obvious that some abilities are more necessary for science than others, but not so obvious that some personalities may make better scientists than others. But studies of scientists - whether as school children, university students or adults - do show a remarkably consistent personality type. Scientists are typically independent, self confident, somewhat unsociable - and uninterested in people,with a non-verbal intelligence bias. Perhaps they are not necessarily so, but at present science seems to attract this type of person.

So what of girls? Again it is difficult to distinguish nature from nurture, but that is relatively unimportant. Perhaps girls are naturally more docile and more sociable than boys. Certainly parents and primary school teachers encourage them to be so. Hutt (1972) reports clear sex differences in young children's play and interaction with others. Girls are more concerned with people and their feelings, more co-operative and less aggressive than boys. From the cradle upwards boys are encouraged to stand on their own feet, while girls are more protected. Boys are expected to solve their own problems, girls can run for help. Boys must not show their feelings, girls can share them with others. Several studies of child rearing patterns (summarised in Maccoby, 1963) have shown relationships between the mother's behaviour, the child's independence and the child's intelligence. The mothers of independent children are found to be less intrusive, demanding and protective than mothers of dependent, passive children. Obviously some children demand more help and attention than others, and this influences the mother's behaviour. But, other things being equal, mothers will generally encourage boys to take responsibility for their own actions, whereas girls are allowed to rely on others for direction. Independence is also associated (for both sexes separately) with a spatial rather than a verbal bias of ability, and indeed with increasing all-round intelligence. Over-protected boys, and boys whose father was absent during their early childhood, tend to have mental abilities similar to girls, i.e. high verbal scores relative to their mathematics scores. These results strongly suggest that children's abilities are affected by their parents' behaviour and that pre-school child-rearing practices, by sheltering girls, encourage in them characteristics which are incompatible with intellectual achievement, and more especially with scientific achievement. These anti-intellectual pressures may not be as strong as those experienced by girls in their teens, but they set a pattern of self-doubt and withdrawal from difficulties.

The process continues when girls enter primary school. Teachers obviously prefer co-operative pupils and will reinforce their docility. Since girls are already strongly orientated towards people and anxious to please, the teacher can generally use approval or disapproval to control their behaviour - a technique which may not be so effective with boys. Thus girls become more dependent and less self-reliant, their reward being not the satisfaction of completing a task, but the teacher's approval. Girls become easily reinforcable, encouraged by minor successes, but discouraged by minor failures. This is evident in Crandell and Robson's (1960) study, where primary school girls prefer to repeat a task at which they have already succeeded, whereas boys will persevere with a problem which is causing difficulty. Liking to be right, girls are conscientious at school, and will learn and memorise, sometimes at the expense of real understanding. But they are unlikely to undertake new projects where the risk of failure is greater.

Let me make it clear that I do not see only disadvantages in these traits. Some, particularly the orientation towards people, may be desirable. But they do have implications (which will be discussed later) for girls' science education, and so it is important to recognise what differences between boys and girls exist.

So far I have been discussing differences between the sexes which may be more or less innate. But more explicit conditioning factors are also operating. Boys learn a considerable amount of science in an informal way through playing with mechanical and electrical toys (Meccano and electric trains), but with girls this is much more rare. Boys are encouraged to help Dad mend the car, while girls help Mum with the washing up, and when boys get a chemistry set for Christmas, a girl is more likely to receive a nurse's outfit. Several recent surveys of primary school textbooks have shown how consistently the woman's role is portrayed as primarily that of housewife and mother, with possibly a few teachers, nurses, secretaries and shop assistants to suggest a restricted world of work. Boy's horizons are not limited in the same way - men are shown in a wide variety of occupations, including those of scientist and engineer. But how many picture or story books include women scientists? Science books have the same defect. One primary school science book has several illustrations of children performing experiments, but only one of these children is a girl, and she is blowing bubbles - a charming, feminine, but not very scientific activity. Some more recent text books do attempt to show boys and girls participating more equally; but the overall picture is that girls and boys will lead very different future lives, and that science has nothing to do with girls' futures. They may even be explicitly told this. Primary school teachers, having themselves accepted a traditional female role, and having in general very little scientific or mathematical background, often label toys and activities as 'for boys' or 'for girls' and direct their pupils accordingly. Torrance conducted a study in the States which clearly shows the effect of this type of conditioning. Ten year old children were asked to explain and demonstrate how science toys worked, and find new things to do with these toys. The girls were reluctant to participate, protesting 'I'm a girl, I'm not supposed to know anything about science', and they performed badly. In a follow-up study Torrance enlisted the co-operation of parents and teachers in an attempt to change the girls' attitude. When retested a year later, the girls were enthusiastic, and performed as well as the boys - although both boys and girls still thought the boys' contribution more valuable! Even where girls are not specifically discouraged from scientific interests, they are unlikely to be specifically encouraged. So it is not surprising if most girls get the message and develop little interest in science.

There is still a tendency to attach more importance to boys' education than to girls'. Parents and teachers will be less worried about a girl who cannot understand maths or science and more willing to let her drop the subject at the earliest opportunity. As shown in Torrance's experiment described above, even when girls perform as well as boys their contribution is undervalued. This reinforces the impression that science does not matter for girls - or indeed that academic achievement does not matter for girls.

Thus by the time they enter secondary school and begin the formal study of science, girls and boys differ in many ways. The relevant differences for science can be summarised as follows:

Girls (1) have less spatial ability and more verbal ability

(2) are less independent, less likely to undertake projects on their own

(3) are less self-confident, and more easily discouraged by failure or lack of understanding

(4) are more conscientious, more likely to study by learning and memorising

(5) are more interested in people

(6) are less interested in science

(7) have less experience with mechanical and electrical toys and gadgets, less background knowledge of science

(8) see a more restricted range of possible roles for the future, which does not include 'scientist'.

Of course not all girls and all boys show all these characteristics. The differences listed here are differences between groups, and individuals may not share all the attributes of their group. Generally speaking, the sexes differ more in attitudes and interests than in abilities, but even so there are overlaps - some girls are interested in how a car works, although that is not the group norm.

Bearing in mind these differences, is it reasonable that boys and girls should follow the same science course? Or, more precisely, is it reasonable - for this is by and large what happens - that girls should follow a science course designed for boys? There are obvious problems associated with running separate courses, chiefly because this emphasises group differences rather than individual differences, and may accentuate rather than diminish stereotyped divisions between the sexes. But there is a case for a multiplicity of courses suited to varied interests and learning styles, or at least a balanced course catering equally for boys and girls.

Within secondary school the sequence of discouragements for girls continues. Many schools have (at least for the more academic bands) two years of general or introductory science, after which pupils can choose whether or not to continue a particular subject to O level. So science has two years in which to attract potential recruits. But several surveys have shown that attitudes towards science frequently decline during these two years, and that the gap between boys' and girls' attitudes and interests widens.

It is not hard to see why. Physics and Chemistry are generally considered difficult subjects, and girls are easily discouraged. Shayer's analysis of the Nuffield courses has shown that much of the early years is at a conceptual level beyond that of most of the pupils. The observational and descriptive aspects of science (which girls prefer because of their greater verbal ability) are stressed less than the manipulative and theoretical aspects. With modern syllabuses rote learning is often impossible and, where understanding is beyond her, a conscientious girl is left with nothing but dislike for the subject. Boys have greater background knowledge and interest when they start science courses, so girls are already at a disadvantage. The teacher, more often than not a man, cannot be blamed for picking topics and examples which appeal to his interests and those of his most enthusiastic pupils (i.e. masculine interests), so further alienating the girls. Science's applications in the factory receive more attention than science's applications in the home. Girls are interested in people, and enjoy subjects where they can express their own opinions. But they feel that science is remote from the world, and that all the answers are already known. Although most syllabuses make some mention of science and society, this is frequently an optional extra, discarded when time runs short. Yet Ormerod's work suggests that girls' attitudes towards the implications of science are an important determinant of whether or not they continue to study it.

The crucial decision for or against science is taken in the second or third year of secondary school, when O level subjects are chosen. Although in theory this may not be a final decision, analysis of course structures have shown how unlikely are pupils who drop science at this stage, to take it up again later. Table 2, which is reworked from Phillips (1970), shows the extent to which choices of O level subjects structure later specialisation. Of those girls who eventually pass at least two A levels, 67 per cent of those who did two or more science O levels study some science at A level, but only 13 per cent of those who took less than two science O levels take any A level science subject. Moreover, 66 per cent of girls who pass two or more A levels are in the group with less than two science O levels, and are thus effectively debarred from studying advanced science. Those girls have frequently taken biology at O level, but their education in the physical sciences stopped when they were thirteen or fourteen years old. Those figures refer only to the high ability group who passed A levels - in lower ability groups even fewer girls study science.

Table 2

Percentage of those gaining two A levels with the given number of science O levels who take any science subject at A level
(Data from Phillips, 1970, Table 2)

	girls %	boys %
more than 2 science O levels	67	75
less than 2 science O levels	13	23

What governs the choices pupils make of subjects to drop or continue studying? The three most important determinants have been identified as interest, occupational intentions (particularly amongst pupils who chose science) and attainment. Attainment more often appears in a negative context (e.g. I gave up science because I couldn't do it) than positively (e.g. I did science because I was good at it). These three factors all fit with the previous discussion to explain why girls seldom choose science - they have less interest in it, cannot see themselves in the occupational role of scientist, and often have difficulty with the subject. Dale (1974) has shown that there is a tendency for a higher proportion of girls to study science in girls' schools than in co-educational schools. Although this is surprising in view of the acute shortage of science teachers and laboratories in some girls' schools it again fits with the previous discussion. In a single sex school the girls will not feel themselves to be at a disadvantage compared to boys and the teacher may take more notice of their interest and learning patterns. There is obviously not the same tendency to identify 'boys subjects' and 'girls subjects' and girls will not feel the need to be constantly emphasising their feminity in these classes. There has been surprisingly little systematic research on the effect of the teacher's sex. Dale suggests that in girls' schools male science teachers are more common than male teachers of other subjects, and attract girls into science. But one might also suppose that in girls' schools a female science teacher - particularly a young, attractive, married one - would encourage girls to study science by providing a possible future role model.

If girls survive all these discouragements and study O level science, what then? Are they well set on the path to becoming career scientists? Apparently not. Table 3a shows that in all the sciences boys increasingly outnumber girls as they progress through the educational system, until in postgraduate physics there is a massive ratio of thirteen men for every woman.

Table 3

(a) number of boys for every girl taking science subjects at different stages in the educational system.

(b) under-representation of girls in science subjects compared to their under-representation in education as a whole.

(Data from Statistics of Education, 1971, Vol. 2, Tables 29 and 31 and Education Statistics for the United Kingdom, 1971, Tables 28 and 29.)

	O level	A level	University students	Post-graduate students
(a)				
Biology	0.6	1.0	1.3	3.6
Mathematics	1.7	3.7	2.6	9.5
Chemistry	2.4	2.9	5.5	11.2
Physics	3.7	4.7	6.8	13.1
All subjects	1.1	1.4	2.3	5.4
(b)+				
Biology	1.3	1.2	1.3	1.4
Mathematics	.8	.5	.9	.6
Chemistry	.6	.6	.5	.5
Physics	.4	.4	.4	.5

+ figures are - $\frac{\text{Percentage of women in subject}}{\text{Percentage of women in education at that level}}$

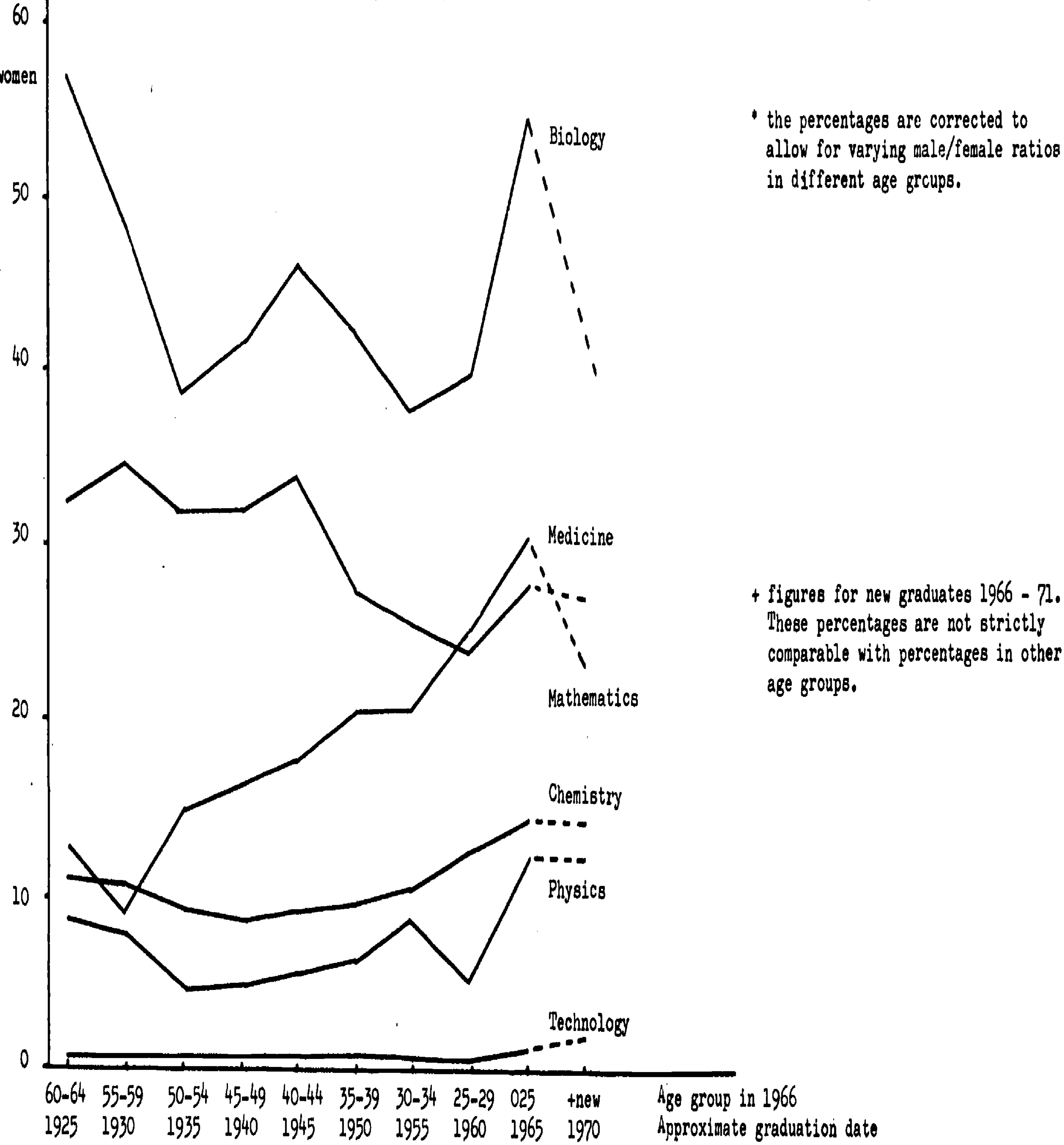
Thus indices greater than unity show that women are relatively over-represented in that subject, whereas indices less than unity show that women are relatively under-represented.

It is during this time - from choosing an O level science course at about fourteen years of age, to becoming a graduate scientist some seven years later - that social pressures are at their strongest. If a girl says that she is interested in science, parents and friends begin to reply 'that's a funny thing for a girl to do'. Many girls feel that boys will not like them if they appear too clever, particularly in a field where the boy considers he should be the expert. Girls and their parents begin to look ahead to marriage and careers but apart from teaching they can see few suitable openings in science. Whereas a boy can become an engineer, this is unthinkable for a girl. As Wynn-Jones has said, for girls 'social science is respectable, biological science is just permissible, physical science is beyond the pale, and engineering absolutely prohibited'. Under these pressures, girls drift out of science. Referring back to Table 2 shows that within both O level categories girls are less likely than boys to study science. Whereas 75 per cent of the boys who have passed two or more science O levels continue science at A level, only 67 per cent of the girls do so; and although 23 per cent of boys with less than two science O levels switch tracks to study A level science, a mere 13 per cent of girls make this change-over. The girls who do remain in science come to feel increasingly isolated, and this isolation, together with the lack of older women scientists whose careers they can use as a model, causes more girls to give up science.

But social pressures affect women's entry to higher education in all subjects. Table 3b shows the percentage of women in science subjects divided by the percentage of women in the educational system as a whole. These indices, which give the relative under-representation of women in science compared to all other subjects, are remarkably stable. In other words women drop out of science at about the same rate as they drop out of the rest of the educational system and probably for the same reasons. What is characteristic of physical science is the low proportion of women. This low proportion is established before O level, and for this reason any attempt to encourage women in science must also operate before O level.

What are the career prospects of women who do study science? At a low level of qualification they are not good - very few apprenticeships go to women, and the only real openings are as laboratory assistants or computer programmers. Only 8.6 per cent of apprentice draughtsmen, compared with 35 per cent of lab assistants are women. Little except anecdote is known about women in these jobs, and one can only speculate on what prejudice and restricted promotion opportunities they might encounter. Certainly girls are biased against industrial and engineering careers because they fear these prejudices and feel that men will resent their presence in a traditionally masculine field (Seear <u>et al</u> 1966).

Figure 1. The percentage of those qualified in science who are women*, in different age groups (Data from Sample Census, 1966: Scientific and Technological Qualifications, Table 7; Economic Activity Tables, Table 3; Educational Statistics for the United Kingdom, 1967-71).



More information is available on women with degree level qualifications in science. Figure 1, drawn from the 1966 sample census shows the proportion of persons qualified in science who are women. Comparing the proportion of women in various age groups gives a cross-sectional view of women's representation in science over the past fifty years - and shows that little has changed. Only in medicine has the proportion of women risen steadily from about 10 per cent of those qualifying around 1930 to about 30 per cent in 1965. Biology, mathematics, chemistry and physics all show a drop from the 1930's figure, although in recent years there has been a slight increase in the proportion of women. The last point on this graph is obtained from the figures for graduates in the years 1967-1971, and so is not directly comparable with earlier figures. However in most cases it shows a drop in the proportion of women and it will be interesting to see if this is confirmed when the 1971 census is published. Only in technology is the picture more hopeful, with the proportion of women pushing up to an all-time high of 2 per cent amongst new graduates.

A high proportion of women qualified in science work - 64 per cent of those not retired or still studying. Amongst married women the proportion is lower, falling to 40 per cent in the thirty to thirty-five age group. But many married women return to work later on in life, and in the forty-five to fifty-five age bracket 60 per cent of the married women scientists are employed.

An analysis of the actual occupations of people qualified in science shows interesting differences between men and women. Table 4 compares male and female scientists and technologists, the women being divided into single and married. Since the women are almost entirely scientists perhaps the more valid comparison is with with men scientists only (i.e. excluding technologists) and these are also shown in Table 4. It is obvious that the bulk of women scientists become teachers. Over 50 per cent of the women are teachers, compared with 24 per cent of the men scientists. However, women are rarely employed as practising scientists or engineers, and rarely move into management. And whereas they have only half the chance of men scientists of being members of a university staff, they have double the chance of being unemployed!

Perhaps women scientists just prefer to teach, but research suggest that this is not so. In reply to a question on teaching intentions only 21 per cent of women entrants to Edinburgh University* science faculty in 1972 indicated that they wished to teach, with 26 per cent indifferent and 53 per cent saying that they did

* This data comes from a questionnaire survey administered by A.F. McPherson to all new entrants to Edinburgh University in 1972.

not want to teach. The corresponding figures for men entrants to the science faculty were 17 per cent in favour of teaching, 32 per cent indifferent and 51 per cent against. For men the proportion who intend to teach agrees fairly well with the proportion who eventually become teachers, but many more women scientists actually enter teaching than intend to do so.

Table 4

Occupations of men and women with scientific or technological qualifications (Data from Sample Census 1966, Scientific and Technological Qualifications, Table 3 and 6)

	Men		Women	
	Scientists and Technologists	Scientists only	Scientists and Technologists Single	Married
	%	%	%	%
Managers	12.1	8.9	0.8	0.7
Teachers	13.4	23.6	51.1	60.7
University staff	3.6	6.9	3.3	3.1
Engineers	34.0	7.5	1.8	0.6
Scientists	12.1	25.4	13.8	7.0
Low level science jobs (e.g. lab assistant)	6.3	5.4	8.0	6.9
Other	17.6	21.1	18.5	18.5
Unemployed	1.1	1.1	2.6	
N (100 per cent)	28537	11981	1181	1024

It seems likely that women scientists resort to teaching because of limited opportunities elsewhere. In a study entitled 'A Career for Women in Industry?', Seear et al show how great are the obstacles. Apart from sheer prejudice, such as believing women to be incapable of certain jobs, or being unwilling to work under women, employers present rationalisations for their attitudes. They are unwilling to hire a young woman - particularly if she is wearing an engagement ring - because they feel that she will soon leave, and her training will be wasted. They are unwilling to hire an older woman, returning to work when her family have grown up, because they feel that her knowledge is out of date and that she will be unreliable, taking days off if her family is sick. These attitudes are discriminatory, short-sighted and ill-informed. Discriminatory in not allowing a woman to make her own career decisions, short-sighted in neglecting to make the best use of available talent, and ill-informed because ambitious young men are as likely to leave and waste their training as young women and older women are remarkably reliable workers.

In these circumstances teaching is popular for several reasons, particularly amongst married women. If they are tied to one place by their husband's job, they can usually get a teaching post near home. The hours are suitable for those with young children and although after several years at home a woman's scientific knowledge may seem out of date in industry it is generally sufficient for school work. An examination of the percentage of teachers in different age groups supports the idea that it is these factors, rather than the intrinsic attraction of teaching, which cause women scientists to become teachers. Amongst those with the greatest freedom of choice - unmarried, under twenty-five year olds - only 34 per cent of working women scientists are teachers. This is probably a better estimate of the proportion of women scientists who, with other opportunities available would choose to teach.

Of course I am not saying that women scientists should not become teachers - only that they should not be forced to become teachers by restricted opportunities elsewhere. At present working conditions in industry - prejudice, the belief that a person who does not work full time and continuously is not worth training, the shortage of retraining facilities and scarcity of opportunities for part-time employment - complete the process of easing women out of science by channelling them into teaching. Research and development work in science is carried out by those in the university, engineer and scientist occupational categories, (see Table 4) and women constitute only 2 per cent of these groups. If persons employed as engineers are excluded, this rises to 6 per cent or a ratio of fifteen men for every woman. Thus only a tiny fraction of those engaged in advancing scientific knowledge or developing new technology are women.

What of the productivity of women scientists? Only 2 per cent of the Nobel laureates in physics, chemistry and medicine, and 3 per cent of the members of the Royal Society have been women. At a more mundane level, interest has focused mainly on the university scientists. The results are not conclusive, but there does seem to be at least some evidence that women scientists produce less useful work (measured by number of publications and citations) than their male colleagues (Blackstone and Fulton, 1974). It is interesting to contrast articles by men and women on this point. Men tend to concentrate on measurables - number of papers published, promotion prospects, rates of pay, hours of teaching - whereas women write about more intangible factors. Cole and Cole (1973) argue, with pages of statistics, that women scientists are less productive than men but they make only passing reference to the arguments of Jessie Bernard, Martha White and Betsy Anker-Johnson (see White 1970). These women discuss the important role of informal contacts and sponsorships from which women are so often excluded. Many collaborations are set up informally and results circulate well before publication but women do not fit easily into this system. Often an older man takes a young colleague under his wing and helps him meet the right people and land the right jobs, but this is not so easily done for a woman. Women may receive fewer citations merely because papers bearing a woman's name are less highly valued than papers bearing a man's name (remember Torrance's ten-year olds!) It is not clear how important these factors are, but it is obvious that women scientists are concentrated in lower ranking jobs (and, in the States, in lower ranking colleges) even when their qualifications and publication rates are equal to men's. This may be because they are not free to move around the country in search of another job, or, as Burrage's survey of women scientists in British universities suggest, because they do not hanker after power and promotion. Nevertheless, it appears that, even within the ivory towers of universities, women scientists are discouraged.

Two interlocking themes have been discussed here - science as a part of girls' general education and the vocational training of women scientists. Professional women scientists face many of the same problems as other professional women, problems which are not specific to science and will not be solved by science. The more important question is probably that of science in girls' general education, particularly since women cannot become scientists if they have stopped studying the subject at an early age. I have largely restricted myself to defining the discouragements as I see them, and refrained from suggesting remedies. But just eliminating the discouragements does suggest some changes, and I would like to finish by speculating on the possible consequences.

It could be argued that if science teaching were altered to accommodate girls' interests and aptitudes, it would no longer be science that was taught. That would perhaps not be a bad thing, at least in the first few years of secondary school. A 'science and society' course might be more relevant to those pupils, of both sexes, who would do no more science, than the fragments of knowledge and method taught at present. Whereas it is obviously important to cultivate enquiry and rigorous modes of thought, it is equally important to cultivate close observation and an appreciation of the implications of one's actions. In other words, perhaps introductory science should aim to give girls a more mechanical outlook on the world, while at the same time encouraging boys to think about the consequences of their mechanistic approach. But what if more girls find they enjoy this type of science and continue to study science up to O level? Will they feel they have been caught by false pretences? Only if it <u>is</u> false pretences, and the subject suddenly changes. Surely it is possible to teach science in a rigorous, and even an abstract way without losing sight of its implications and applications. And what if these measures did produce more women scientists? Would they do a different sort of science? I think so, but I would not like to predict what it would be.

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TEACHING SCIENCE: ALTERNATIVE JUSTIFICATIONS

Roy Schofield,

Senior Lecturer,

Department of Education,

Brunel University.

Teaching Science: Alternative Justifications.

In recent decades there has been a tendency to discuss most issues connected with the curriculum in terms of one or other paradigm of the educational process. Countless books and papers have carried forward the slow elaboration of the story first told by Tyler some twenty five years ago. I need hardly labour the point that although this overall view of the curriculum has been taken up with degrees of enthusiasm which range from the evangelistic through the indifferent to the frankly horrified, the net effect on school curriculum planning has, in the event, been to focus attention onto what have come to be known as the objectives of the curriculum, and in particular onto classroom mediated behavioural objectives. By 'classroom mediated behavioural objectives' I mean those changes in pupil behaviour for which, in principle at any rate, we can entertain the possibility that the pupils' attendance at the school may mediate the desired change in a more or less direct manner. It is of course true that this kind of objective is very much what education in science has always been about.

There are pitfalls however, and we have not always avoided them. In particular we have, and not only in science education, tended to forget that however subtle and complex the model we erect of the process of education, it will not - and cannot - generate for us the objectives which are our input into the model. We have ways and means of attaining the objectives with which we work. What we have failed to do is to give equal attention to the prior issue about the origin of our objectives. Why do we teach Ohm's law? Why do we believe it to be important that we teach something of the process of discovery and so on? Indeed it is strange that after two and half decades, and more, of thinking of the classroom in terms of the attainment of specific objectives, we are, today, more than ever in need of serious thought at a basic level about the value system which underlies any listing of objectives and without which, indeed, such a listing could not exist. If what I have to say may be thought to have a purpose, it is the attempt to discuss alternative justifications which have been made - and are being made - as the underpinning of science teaching in schools. It is my hope to show that before we are able to hold rational notions on the issues of concern to this conference we must first be able to relate our decision to a coherent set of beliefs on which the objectives of our science education rest. For it is only if we are able to enunciate and maintain such a belief system that we will be able to extrapolate to questions of a rather finer structure, such as those concerned with the education of girls.

Let me illustrate; when we ask questions of the kind given below we are, it seems to me, asking for answers which can only be given in terms of a prior set of value judgements made in the context of science education as a whole.

Should we be concerned if the sciences appear to be 'masculine subjects' in terms of O and A level entries?

If, as appears to be the case, girls are more likely to fail to choose science subjects because they perceive science as a force for social evil, ought we to more strongly stress its more positive social consequences?

Any answer which is given unrelated to a clear statement of why we presume to teach science to anybody is, or so I believe, essentially ad hoc and, taken with other such answers, can only lead to a confused and unarticulated form of science education. It is of importance, and not merely of interest, to attempt to delineate the various views which are held as to why we teach science and what we therefore ought to teach. There is of course nothing novel in such a discussion; it could be described as prosaic. In spite of this it can hardly be done too often, because time and time again one comes across discussion in the field of education in which the participants are failing to communicate simply because their value systems differ, and they do not know it.

If I ask my students to justify the circumstances that the State is proposing to pay, at present day prices, a sum of around £160,000 for their life-times work in the teaching profession I am, more often than not, met with a glance of incredulity that such a question could be asked in the first place. First answers, when they come, tend to be couched with differing degrees of sophistication, in terms of the 'Mallory response'. It will be remembered that Mallory, when asked why he embarked on the awesome task of climbing Everest, replied: "Because it is there". In a similar manner science 'is there' in schools and so we teach it. How many of us here I wonder, who have been, or are, involved in teaching science, have at some stage of our career required no more justification than this - I know I am one!

A first reaction is to dismiss such a justification, for at first sight it appears to be little more than an alternative way of saying that we have no value system on which to base our science teaching. Things are not, I believe, quite as simple as that. For we would not be able to give the same answer if asked to justify the teaching of, say, clogmaking. For unlike Everest, clogmaking (as a school discipline) is not there. Why should this be? Presumably it is because in the recent past enough people have been able to enunciate a sufficiently convincing case for the teaching of science and not for clogmaking.

When I make the point to my students that the reasons they have given are honest but can hardly be said to be fully satisfactory they almost always then fall back on the instrumental. We teach science, they say, because if we did not we attitudes and motivations to behave as scientists and technologists, without whom society as we at present organise it would collapse in chaos. When next, and perhaps somewhat sadistically, I press the point that in truth such people are in a rather small minority in society and yet we ask that science be taught to all our pupils, my students usually take the opportunity to ask me to coffee. I have to say that one car hardly blame them, for in the schools themselves any discussion - if there is one - rarely, if ever, moves beyond the justifications, such as they are, that I have given.

To wander off the subject for the moment - the instrumental justification is often rather summarily dismissed as hardly being worth discussing. In books on the curriculum one comes across statements such as: "The circumstances that many, if still a minority of our pupils, will work as scientists of one sort or another is not the only, or indeed an important reason as to why the subject is taught in school." To imply, as statements of this kind do, that the instrumental reason even if incomplete is not an important one is surely wrong. Given that in the present structure pupils are expected to enter the field of tertiary education already partially introduced to the current scientific paradigm, it is not easy to understand how schools can totally abdicate this responsibility without some pretty wide ranging consequences, for the Universities are just not equipped, either in resource or in attitude, to undertake this task as other than a fringe activity at the present time.

We are now passing out of an era during which educational economists tended to describe education in terms of input and output economics. They have realised that much of the consequence of the educative process cannot be quantified in simple monetary terms; a realisation that owes much to the writings of my colleague Professor Vaizey. However, in practice we often justify expenditure on science education in terms closely allied to the vocational and economic, whatever our lip service to wider education. Dainton did not get over-worried, or so it seemed to me, about the fact that by deserting science some pupils may have been turning their backs on an opportunity to enrich their lives, but rather because without them the generators of the CEGB could eventually stop turning.

It is now time to pause for a moment and ask if value judgements of this kind have any relevance to girls and science education? It is difficult to see that anyone simply teaching science 'because it is there' can justify any views he may have. Not everyone climbs Everest and if rather fewer women than men do so, it is not really a matter for comment. Certainly we would - if this was our sole justification - have no rational grounds for any action we might propose. On the other hand if we rest our case on the instrumental value of science education we have, or more precisely we may have, such grounds. If it were demonstrated enter into scientifically based occupations were so doing, and it were also to be demonstrated that too few were entering these occupations, then it would follow that efforts should be made to persuade girls to embark on science courses in greater numbers. There was a short period of a few years in the early sixties when such efforts were made. Alas in many fields it is now a non-issue. The problem is more one of how to employ those who are fitted for a scientific occupation. In this kind of situation it might be held by those who basically accept an instrumental or vocational justification for their work that, all in all, it might be wise to dissuade girls from taking science subjects in secondary schools at this time.

Let us ease ourselves gently into a wider range of justifications by looking at an old Ministry of Education Pamphlet (number 38) published in 1938. We read that in addition to vocational grounds science can (and I quote) 'on the one hand provide that knowledge of the physical world without which intelligent action and thought under modern conditions is impossible; on the other hand it can furnish within a suitable field a training in consistent thinking'. You will of course recognise here a Ministry distillation of frequently stated justifications. And if only it were so simple! How easy my task would be if it were indeed the case that we would be incapable of intelligent action and thought without some education in science. Alas this can't be the case. If it were, at least half the Cabinet would need to be classed as morons and, whatever our views, few of us would be prepared to go quite as far as that! As for the vast majority of those we pass in the street we would have to accept that they are incapable of intelligent action and thought in the modern world. I very strongly suspect this line of argument and so does someone much more able to judge, for Jevons has this to say: 'Considered merely as information ..... there are a great many scientific facts that must rank very low ..... how important is it really to know some picture of electrons whizzing when the electric kettle is switched on?'

As the lives of millions of our fellow citizens show, it is perfectly possible to live an effective and full life without scientific knowledge of any kind, so girls cannot be fundamentally disadvantaged if they fail to acquire it.

It can hardly be said that the then Ministry were on a much better wicket in giving the second of their justifications. It is not too easy to see quite what is meant by 'consistent thinking'. This is not the best place to rehearse the pros and cons of transfer of training and in any case I am not qualified to do it. What one is able to note is that the science we teach in school is not conspicuously any more consistent than are many other subjects; one cannot avoid the suspicion that the Ministry author saw science as a rational tautological system rather than as an experimental, model building, activity. All of which is, about girls and science. If they could not be intelligent without science, it would indeed be a chauvinist male pig who failed to encourage girls to undertake its study. Similarly, if it really were the case that training in consistent thought were given in the average science course, we certainly would need to avoid allowing girls to disadvantage themselves by withdrawing from science courses.

Let us look now at another kind of justification. It is a quotation from Mary Budd Rowe, a distinguished American science educator.

'Most modern elementary science programmes, when properly taught, probably can contribute to a sense of fate control and a probabilistic view of nature.'

I have chosen this piece because it is pretty typical of many that may be found in the literature.

This we might begin to think is very much more like it. Is this perhaps the kind of thing my students should tell me at that point when they invite me to coffee? Mary Rowe is here arguing for the inclusion of science because of the way in which she believes it changes the pupil's view of the nature of his life, his perception of his life space. (Notice the intrusive 'his' !) This is a large claim if stated in this way and in any case such a justification is very clearly value laden. Ms. Rowe takes it as given that we would wish to increase a sense of fate control in a child. It is not for us to enter into a discussion here on justifications of this kind, but what we can see is that once we begin to underpin the objectives of our science programmes with value judgements of this kind we are justifying the teaching of science because of its influence in terms of the kind of life the pupil will subsequently lead. It is clear that if we were to subscribe to the justification given by Ms. Rowe we would find it difficult to rest content with a situation in which one of the sexes was able to (say) increase its sense of fate control while another were not. We are here, or so I believe, attempting to justify the teaching of science in terms of the human predicament and there has seldom been the claim that one of the sexes has the edge in this.

Before we leave this particular justification - and I take it as representative of all those justificatory claims which are in some way based on the power of a suitably written science curriculum to basically alter a pupil's perception of his 'life-space', it may not be out of place here to ask if, putting aside all questions of value, it is a credible aim in the first place as thus stated. There is one sense of course in which it is. If the curriculum has as its intention the induction, or at least the first stages of this process, of the pupil into the current scientific paradigm, and if we remember Kuhn's shorthand description of the paradigm to be 'that constellation of beliefs, values, techniques and so on shared by the members of a given community', then we may accept that there will be an influence of a very different kind to that which would follow induction into that paradigm shared by an African Witch cult. In the one we would be expected to show a sense of fate control as opposed to a sense of being controlled by fate.

You may find the contrast with an African cult rather far fetched. A little extreme it may be, but anyone who has had the opportunity to read Horton's influential paper in Young's book 'Knowledge and Control', in which he - in the time-honoured phrase - 'compares and contrasts' the paradigm of Western Science with that of the Witchdoctor, will hesitate to use the word 'far-fetched'. Let us come nearer home. There are in our schools, and not least in our more prestigious ones, pupils who because of a rather loosely drawn curriculum allied to their own ingenuity have been able to avoid pretty well all real contact with science. At any rate we all know pupils - and here I am thinking particularly of able boys and girls - for whom any talk of induction into the paradigm of Western Science would indeed be a nonsense. To what extent, we may well ask, is their sense of fate control any the less than that of the brightest light of the scholarship science sixth? What I am getting at is this - we ought not to too uncritically accept claims for a scientific curriculum - or any curriculum, for that matter. Any presence or absence of a sense of fate control (or whatever) is much more likely to arise from the totality of the culture in which a child is brought up. To reverse the argument, if our curriculum had African Witchdoctoring as a component we would in all probability be living in a society in which African Witchdoctoring was a predominant cult.

I have spent a length of time considering differing justifications for teaching science which might be regarded as excessive. I have done this because I think the issues are important. If we are concerned that girls are not taking the opportunities afforded them to study science, it is very important that we critically examine the justifications we propose for having the subject as part of the curriculum for anybody.

I can well imagine that you are beginning to think that I may be an example of the kind of person who is all too common nowadays. I am here referring to those who, having gained much by being exposed to a particular form of curriculum, are busily engaged in dismantling it with the effect that their children - and ours - will be unable to profit as they have done. However, it is not my intention to demonstrate to you that we should not be teaching science, but like so obvious as we often seem to think. I have been giving reasons why I regard some of the justifications often given as weak and open to objection. The trouble has been, I think, that in the past there has been an unfortunate fragmentation among curriculum workers. In particular there has been a dichotomy between the active science curriculum builder and those philosophers and sociologists who have been thinking and writing about the curriculum as a whole in terms of their own disciplines. A direct consequence of this split - which one should at once hasten to add is now being bridged - is that we have, or so I think, tended to underpin our science curriculum with a totally inadequate value system.

What then are the justifications which may be regarded as more viable? The Phenix thesis is well known and is the common change of Colleges and Departments of Education. I am unsure as to how much the thrust of this particular thesis is known in the schools and in places where curriculum matters are decided, as opposed to talked about. Education, for Phenix, is a process through which the pupils are to develop the power to gain meaning from their perception of the world. Indeed he sees the curriculum as being concerned with the engendering of meanings. Further he argues that humanity is able to structure experience meaningfully in a variety of ways, through aesthetic and through religious experience for example, and he calls these realms of meaning (the title of his well known book). One of these realms of meaning is that which he designates as empiric; the realm of statements framed within an experimentally verified system.

The consequence for the practical curriculum is apparent. 'Without these a person cannot realise his basic essential humanness. If any (of the realms of meaning) is missing, the person lacks a basic ingredient of experience. They are to the fulfilment of human meanings something like what basic nutrients are to the health of an organism.' (My emphasis).

Hirst has arrived at a not dissimilar position by arguing that the disciplines of the curriculum - mathematics and logics, physical science, history and human sciences, literature and fine arts, morals, religion and philosophy - are all distinctive and not derived one from another. Hirst proposes that all other forms of knowing derive from these basic forms. We see how the outcomes of his view coincide with those of Phenix. Each would argue that in denying a pupil access to one or other form of knowing (Hirst) or realm of meaning (Phenix) not only would he or she be denied that particular imaging of the world (effectively perhaps for life) but also denied all those other fields of knowledge depending on these forms. For example a physical geographer (and physical geography is a good example of what Hirst means by a field of knowledge) who had no education in the natural sciences might be thought to be a contradiction in terms.

Now both of these formulations may be and have been criticised; not least because in neither of them does it seem that the concept of a truth within a form of knowledge (or a realm of meaning) is sufficiently analysed. There is a faintly Nineteenth Century air about the picture of the natural sciences which comes through in either work. If, for a moment, we take the general argument at its face value, however, we see at once that it has direct relevance to our main theme. Unless we are prepared to argue that for some reason girls ought, as an intrinsic part of their place in society, to be denied a full opportunity to (in Phenix's terms) realise their essential humanness, we should not so allow the the general culture and the institutionalised general curriculum to combine in allowing and encouraging them to opt out of studying scientific subjects.

I made the point earlier that I did not think that an able pupil who had managed to avoid all our efforts to introduce him to Bunsen and Avagadro would have a different attitude to fate control for that reason alone. I do think he might have rather restricted mental furniture in comparison with that he would have had if he succumbed to their attractions. It is this restriction of possibilities for their own development as people which causes one to have concern when we look at the way in which girls seem to avoid the sciences both in and out of school.

At this point some might well feel that journey's end is in sight and our consciences being quieted we can get on with the business for which we are gathered. If the educational philisophers give us good reason for the inclusion of science in the curriculum and if that reason does not appear to differentiate between boys and girls what then are we waiting for? As we well know the world is never that simple. A very important question has been begged, for it has been assumed in all that I have said - and in much that others have written - that it is possible to teach to all pupils a form of science curriculum which makes sense in the light of the Hirst/Phenix thesis. It is at this very point that we should I think be concentrating all our efforts at this time. A Scotsman, Davie, when discussing the differing ways in which he holds it is possible to carry forward the exact sciences has this to say:

".... the former method as perfected by the great French algebraists, while it made possible the great advances of science, nonetheless threatens in industrial conditions, to separate the specialist scientist too much from the rest of society, thus paving the way for the social moronisation of which Adam Smith warned. It may well be .... that unless there is a vast educational effort to re-express the point of view of science in holistic terms which can reach the general populace, society will, to its ruin, cease to identify with the science which is its moving principle."

Insofar as the Hirst/Phenix thesis considers science to be a 'form of knowledge/realm of meaning' it is science per se which is under discussion. Now as Davie so eloquently implies science per se is fundamentally analytic, its dynamic is towards discreteness. Allied to this analytic mood there is as corollory quantification of physical quantities and their mathematical manipulation or at the least their logical manipulation i.e. we infer. We have I believe to accept that the ability to carry out such operations whilst by no means being restricted to a kind of 'priviledged elite' is not possessed by absolutely everyone. In particular it is for the differential and social psychologists to seek the reasons why in our society it would appear to be girls who are, in Davie's terms, more likely to cease to identify with the science which is society's moving principle. I simply hope to make the point that to take up the position of the Hirst/Phenix thesis may not be enough unless we regard ourselves as being concerned only with the curriculum of the intelligent and scientifically talented.

Michael F.D. Young has argued for a form of science curriculum centred on the classroom interaction of teacher and taught and no longer anchored in the subject discipline. Quite what such a curriculum would turn out to be in practice is an open question for it is, as yet, not anywhere operational. Insofar as one is able to put practical bones on the skeleton he has drawn for us it would seem to demand a science curriculum which involved teacher and taught making an attempt ab initio to make some kind of sense, in their own terms, of their observations of the world of the senses. It would not so much be a question of devising a discovery method of teaching science, but rather of devising a 'discover your own science' method of teaching. Young makes the point that almost by definition such a science would be holistic and Gestaltic and founded in common sense. It may, he specifically argues, be the case that such a science would not result in the attribution of failure to girls.

It is the case that Young and his co-workers are under very heavy fire at this time; not only, it must be added, from the hard core traditionalists who are, in matters of curriculum, in such a big majority in our schools, but also from a section of the political Left who see the danger of permanent disadvantage to the working class if a situation is allowed to develop in which the working class children in our state schools discover their own science whilst those children in independent schools are led along well worn paths to an acceptance of the current scientific paradigm which, as it so happens, enables them to design electrical trains, computers and atomic power stations. One can see their point; not only would we have a middle class that had access through privilege to opportunity, but they would in a quite direct way become a kind of scientific priesthood. All this said, however, the issues he raises will not go away - if we impose failure through our choice of science curriculum, it could well be that we impose more failure on girls than on boys and it is interesting to speculate on the cost to the ultimate stability of our form of technological society. I have been rambling on rather so I must make it clear once again, for I feel sure that such a thread as my argument has has become a little obscure, that I am here considering the science curriculum in the context of all pupils. Self evidently if we are concerned solely with the instrumental justification, we have no option but to teach with the authority of the current paradigm behind us.

Before I attempt to come to some kind of conclusions, I feel it worth while to draw attention to research that was done about six years ago and which has not, I believe, received the attention which is its due. I refer here to the way in which, by whatever route it arrives, there is in our society a perception of the scientist as a person, which related as it is to a view of science as an activity, may best be described as a myth. The work to which I refer was done by Liam Hudson. He sought to investigate the picture of a scientist as opposed to a person educated in the humanities which was carried in the population. He sought, if you like, the common stereotype of the scientist. In introducing his topic in his book 'Frames of Mind', he quotes two American psychologists who summarise the American student's view of the scientist in the following terms:

"First the scientist is characterised by high intelligence dissociated from artistic concerns and sensitivities ..... Second there is a clear lack of interest in people. ..... (He is) self sufficient, rational, persevering and emotionally stable ..... The personal life of the scientist is thought to be quite shallow, his wife not pretty and his home is not very happy ..... (He is) a masculine figure in a de-sexualised way."

Now stereotypes like this don't arise by chance; they must come from somewhere. As Hudson says, we also need to know just who holds such views. Are they, for example, shared by scientists themselves? Do <u>they</u> think that their wives are less attractive? Hudson queried some 390 schoolboys aged between 12 and 17 (and all quite bright). The method he used was that known as the Osgood Semantic Differential. In thi[illegible] subjects of the experiment rate selected figures: - Biologist, Novelist, [illegible]an etc. against pairs of adjectives - warm/cold, intelligent/stupid and so [illegible]. "The subject makes large numbers of judgements at considerable speed and one trusts he will be influenced by intuition more than by rational deliberation." In this way one hopes to tap a stereotype. The surprising fact that Hudson brougnt to light was that there was little difference between the pictures arrived at by the boys studying the arts and those studying the sciences.

They all saw the Physicist (say) as dependable and the Novelist as warm but undependable. They all saw the Novelist's wife as being exciting, feminine, soft and imaginative, whilst again the Scientist's wife had to be content by being thought dependable!

In another experiment Hudson asked his subjects to rate a typical arts graduate and a typical science graduate on specific and general attributes which he listed. Both arts and science specialists agreed that the arts graduate was more likely than the science graduate to wear fashionable clothes,
to flirt with his secretary,
to be sociable,
to like expensive restaurants,
to like his wife to look glamorous etc.

In contrast, the science graduate was seen by both arts and science specialists
to work long hours,
to be faithful to his wife,
to be embarrassed about sex etc.

Now whence come these myths? - and I suppose that we here today do agree that they are myths! Hudson himself obviously has doubts. Perhaps he says we act out our myths; "is it not possible that if scientists do have dull lives and dowdy wives, they do so solely to act out what they perceive as society's expectations of them?" (Notice here, by the way, the sexist bias of his actual statement.) Well, I have little doubt that the stereotypes come in part from the way in which we teach science. Hot from the press - or almost so - I have been reading a paper by Smolicz and Nunan in Volume Two of Studies in Science Education. There is in it a section headed School Science as Mythical Science. The paper is far too complex to precis in a few paragraphs (or even pages) and in any case I am far from certain that I yet understand it. The case is made, however, that science as an activity is far more complex and confused than we have tended to imply. We have, for example, commonly talked about a scientific method. As the paper puts it: "to the educator the peculiar common denominator is the scientific method. Scientists, by adopting this attitude to knowledge, become imbued with mythical attributes that enable them to act as free, disinterested and uncommitted observers applying a special logical thinking process to their raw data ..... Science badly taught gives the impression that all that it does is to use such an unimaginative mechanical routine."

I could go on in this vein, but I hope I have made Smolicz and Nunan's point and I hope that they way in which it links up with Hudson's findings is clear. I think we create a myth and I do think that the myth contains an image of the scientist which has puritanical and masculine connotations. Certainly it is not a picture which, whatever else it may or may not do, is likely to lead girls to study science in greater numbers.

If we accept the drift of the above argument we do certainly need to view the interaction of science and the female 'avoidance behaviour' of girls as being evidence of an unreal stereotype of both scientists and of scientific activity. Of course the diagnosis is easy, a remedy takes a little more time. Let me illustrate. In the past one of the failures of our teaching has I believe been a neglect of the place of the use of the model in scientific thought. A consequence of this neglect has been a view of science deficient in imagination. There is all the difference in the world between telling a class that gases were found to be a lot of particles moving about at high speed and putting the more sophisticated view that the consequences of imagining that a gas was rather like a lot of little particles - etc., were in one-to-one relationship with the facts that arose from a study of the varying parameters of the gas. In the one case we are in the world of a man or woman who is unlikely to wear fashionable clothes; in the other in the world of attractive wives. The snag here however is apparent to anyone who has attempted to teach the idea of a scientific model to all except relatively gifted pupils. Perhaps it can be done but I have not succeeded and I know few who have! So once again we are back with Young.

I must now attempt to summarise. Most future teachers of science when asked to justify their work do so in terms of a job to be done or in instrumental terms. Neither of these justifications is wholly satisfactory and only the latter leads to concern when girls fail to study the subject (and that only when there is a shortage of scientists).

Many other justifications which have been given are in varying degrees deficient and little if any concern can be founded on them alone. However, I have put the view that perhaps we can justify our work in the light of a view of the curriculum depending on the arguments of either Phenix or Hirst. If we accept such a view we are able to find ground for a proper concern. For it is a consequence of such a view that if girls generally avoid science they may well be cutting themselves off from valid experience and hence unnecessarily limiting their wholeness. In the latter section of my remarks, however, I have been concerned to question the form of the science curriculum we have traditionally offered and have indicated criticisms that have been made of it both on sociological grounds and in terms of the mythology to which it can give rise. It may well be that if we search for a science curriculum which is found to be more attractive to girls, we may be on the road to a science curriculum which is more generally appropriate for the all ability schools of today, and which additionally is more descriptive of science as an actual activity.

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GIRLS AND BOYS: ARE THERE DIFFERENCES IN ABILITY?

Dr. Esther Saraga,
Lecturer in Psychology,
Department of Sociology and Psychology,
Chelsea College.

Girls and Boys: Are There Differences in Ability?

Introduction

Any discussion of psychological sex differences must begin with some cautionary remarks about the interpretation of findings. For this particular conference it is also important to consider whether the existence of sex differences in ability has any relevance to our discussions.

It is clear from a review of the literature that there are some fairly consistent differences between the average scores of females and males on certain types of task. However, there is also considerable overlap in the distributions of those scores. This means that statements about average female or male scores provide no information at all about individuals of either sex. (This point is one which is well known, but frequently ignored; it is particularly important for a conference like this one, which is presumably concerned with the practical implications of the questions discussed). For this and other reasons it seems to me to be doubtful whether the question of sex differences in ability is particularly crucial, or even relevant, to the problem of why girls don't do science. However one very good reason for considering this question is that within the psychological literature there is a growing body of work strongly emphasising biological bases for various differences in ability. Moreover the authors seem to imply that there are quite strict limitations on the range of activities that girls and boys are each likely to be capable of. This work is becoming increasingly well known and may, at a later date, seriously enter into educational discussions. This alone makes it an extremely important question to consider.

The main part of this paper will consist of a review of the literature on sex differences in ability, the relevance of these abilities for success in science, and evidence relating to biological and social factors contributing to their development. However, before discussing the psychological literature, I should like to make a few general points which are important to bear in mind when interpreting particular studies.

Firstly the question of overlap in the distribution of female and male scores which was mentioned earlier. The degree of overlap in scores is often not reported in papers. Even when it is reported it is not always meaningful to the fairly casual reader. In particular, it is important to realise that a significant difference in the mean scores of females and males does not rule out the possibility of considerable overlap. Anastasi gives an example of distribution of scores for an arithmetical reasoning test which show a significant difference between boys and girls. This difference can also be expressed as '28% of the girls reached or exceeded the median score of the boys' (this is the usual measure of overlapping). Th graphical representation of the distributions shows that the overlap is considerable. (Anastasi, 1958 p.455).

Psychologists working in this field do not always take the overlap in scores into account when drawing conclusions from their studies. For example in an extensive review of sex differences, Garai and Scheinfeld report that boys and girls approach mathematical problems in different ways - boys adopt a broader, more integrative approach. To the reviewers this suggests th boys and girls should be taught by different methods in mathematics, since girls are hindered by the traditional 'masculine' approach to problem solving. It is clear that such a policy would be retrogressive if ther is a considerable overlap in the distributions of performance for the two sexes. Even if it were possible to relate teaching methods so directly to ability, such segregated teaching would be quite inappropriate for large numbers of both girls and boys. (This is quite apart from the more general negative social consequences likely to result from segregated teaching situations.)

Secondly, the description of sex differences in ability does not in itself provide any information about the relevance or importance of particular abilities for achievement in science. Many authors assume, for example, a relationship between analytical or spatial thinking and scientific ability. This relationship does seem to be intuitively reasonable; however there is relatively little direct evidence on it. As Alison Kelly has pointed out elsewhere 'Connections between science and these intellectual abilities are generally a matter of supposition rather than experiment.' Even those studies which have looked directly at this question do not show a consistent pattern of results. Moreover there is a tendency to describe 'science' as a single intellectual activity ignoring possible differences between different scientific disciplines.

Thirdly, the term 'ability' can be misleading. In particular, although consideration of spec. . kinds of abilities is preferable to the notion of IQ or 'general intelligence', the term 'ability' seems to imply the existence in the brain of some capacity wh h is fixed or which can vary only within a fairly limited range. It is more accurate to think in terms of different kinds of information processing in the brain.

In addition, the separation of 'ability' and 'personality' characteristi rtificial one. It often forgotten that what is actually measured in 'bit of behav ur' - i.e. the subject's performance. This expectations, motivation etc., as well as by specific abilities. There are many examples of this: girls' performance on problem solving tasks is much more disrupted by anxiety than boys' performance; girls who have performed as well as boys still have lower expectatio .f their subsequent performance on the task; girls and boys matched for specific abilities still show differences in performance in problem solving - the boys . better. Thus it is clear that there is far more to achievement than pure ability.

Finally, many people will ask, and this question is becoming more fashionable, "are there any 'inherent' differences in ability between girls and boys, which set a limit on possible environmental manipulations?" The answer to this can only be that there may be, but that these limits are probably only reached by very few people - perhaps some individuals who suffer actual brain damage. The recent psychological work in this area has, I believe, developed into a rather naive and sterile nature <u>versus</u> nurture argument. On the one hand there is a growing body of work emphasising the biological basis of most psychological sex differences, and which seeks to account for these differences in evolutionary terms - as a remote but necessary consequence of female and male reproductive roles. This approach, which is represented by Buffery, Gray and Hutt, is generally associated with a neglect or underemphasis of social factors contributing to development. Where social factors are discussed they are limited to external factors such as differential treatment of the sexes by parents, or inequalities of opportunity. It is also important to take account of the individual's internalisation of social expectations as part of her or his sex role identity. Deviation from the stereotypical role can cause the individual great conflict. On the other hand, some social psychologists and sociologists are guilty of an extreme environmentalism. Both these approaches ignore the fact that humans are biological organisms whose development all takes place in a social environment. A further inaccurate assumption frequently made is that anything biologically determined is unmodifiable, whereas anything environmentally determined is infinitely modifiable.

It would not be appropriate here to enter into a detailed discussion of the biology versus culture argument. (This can be found in Ounsted and Taylor, 1972 - articles by Hutt, Buffery and Gray; and in Archer, 1971; Archer, 1975; Archer and Lloyd, 1975 - criticisms of the former approach). It should be noted, however, that the increasing interest shown in arguing the case for a biological basis for sex differences means that this work could be used in future as an excuse or scientific justification for educational or social policies which discriminate against women.

Studies of Sex Differences in Ability

In describing a particular difference in performance between females and males as a 'sex difference' it is important to take account of the stage of development at which it is observed, and its persistence into adulthood. One of the probable biological influences on sex differences in childhood is the faster developmental rate of girls compared with boys. Girls not only reach physical maturity earlier, but throughout childhood they are further advanced towards their adult status. Several writers have inferred by analogy that girls may also be accelerated in intellectual development. If this is the case, comparison of boys and girls of equal age is problematic. In particular there are several tasks on which girls perform better in early childhood, but in many cases boys catch up and overtake in later childhood and adolescence. Only if female superiority on a task persists into adulthood is it accurate to describe it as a task at which females excel.

. Tests of General Intelligence

In general girls do better on intelligence tests during primary school years; boys catch up and overtake by secondary school.

However, these tests are not really suitable for testing sex differences - for two reasons: firstly, when these tests were constructed sex differences were eliminated by removing or counterbalancing those items on which one sex consistently scored higher, since it was assumed that the differences were due to an environmental artefact. Secondly, the use of a single score over the whole test obscures differences between individuals or groups on specific aptitudes. In fact it was the discovery of consistent sex differences on various subtests that led some testers (e.g. Wechsler) to produce different norms for each sex on these particular subtests.

These findings led to a focus on 'specific abilities' in the study of sex differences.

2.Tests of specific abilities

In general, females are found to perform better on tasks of perceptual speed and accuracy, rote memory, manual dexterity, language usage and verbal fluency.

On the other hand, males perform better on tasks requiring spatial orientation, analytic ability, arithmetical or verbal reasoning, numerical reasoning

Several authors have summarised the different 'cognitive styles' which arise from these sorts of differences. In its simplest form, the difference is described as one of 'verbal versus spatial' ability, which certainly gives the impression of a qualitative rather than a quantitative difference. However, as I shall discuss later, the term 'verbal ability' used to describe skills at which females do better, is rather misleading. Moreover, other authors have given more detailed descriptions for which it is much harder to avoid value judgements. For example, Broverman et al (1968) suggest that tasks on which females perform better can be described in the following terms:

"The behaviours appear to be based mainly upon past experience or learning, as opposed to problem solving of novel or difficult tasks .....
As a result of extensive prior experience, the behaviours appear to involve minimal mediation by higher cognitive processes .....
..... the behaviours are evaluated in terms of the speed and accuracy of repetitive responses ... rather than in terms of production of new responses or 'insight' ...."

In contrast, for the tasks at which males perform better:
"the behaviours seem to involve extensive mediation of higher processes as opposed to automatic or reflexive stimulus-response connections ... the behaviours are evaluated in terms of the production of solutions to novel tasks or situations ... as opposed to speed or accuracy of repetitive responses."

Before describing the sex differences in specific skills in greater detail, it is important to emphasise that they are inferred from performance on particular tasks. Different tasks have been used by different authors to assess (e.g.) spatial ability, and many tasks appear very 'strange' to the subjects (Marshall, 1973). Very rarely is there any direct analysis of the information processing requirements of a task. Marshall comments that the labels 'linguistic skill' and 'visuo-spatial skill' offer little help in understanding the formal nature of the abilities referred to. He suggests moreover that the apriori likelihood that all subjects approach these tasks in the same way is not very great. Commenting on similar problems, Coltheart and his co-workers point out that tasks described as 'spatial' could be carried out by verbal processing and vice-versa. (They also quote evidence which suggests that this does occur in some cases.) These authors have devised much 'purer' verbal and spatial tasks than those generally used. These will be described later. For the present I should simply like to emphasise the need to consider the 'task' as much as the ability assumed to be involved. It should be noted that authors, and in particular reviewers, rarely give much detail on the tasks used.

(i) Verbal abilities

In the preschool and school years girls excel; they say the first word sooner, articulate more clearly, and at an earlier age, use longer sentences and are more fluent. In line with this boys show a much greater frequency of speech and language disorders. In general, the linguistic development of girls is said to 'run a much steadier course' from an earlier age in female infancy. Boys' performance is much more erratic.

The verbal superiority of adult women is shown in tasks involving acquisition of the mechanics of the language (spelling, grammar, punctuation etc.) and in tests of word fluency (naming words in a given category, telling stories in response to stimulus pictures, rhyming words etc.). However, women are not better at vocabulary (boys catch up with girls very quickly and end up with a much wider range), nor at verbal comprehension or verbal reasoning (a measure of the ability to understand concepts framed in words - such as analogies).

Since the female 'superiority' is found in the 'executive' aspects of language, several authors have suggested that it should be described as 'linguistic ability' rather than 'verbal ability'.

(ii) Motor skills

From infancy on, boys are stronger and better in speed and co-ordination of gross bodily movements. Thus they perform better at tasks such as walking on narrow boards and throwing a ball. They also show faster reaction times.

On the other hand, girls tend to perform better on tests of manual dexterity. They can dress themselves better, and are better at tasks like buttoning, tying bows and turning door knobs.

However, it is not clear that 'manual dexterity' should be treated as a single ability. Tyler (1965) points out that proficiency at one manual skill does not necessarily imply proficiency at another.

(iii) Memory tests

Girls appear to be generally better at tests of rote memory, however the results in this area are not entirely clear nor consistent. Thus, although girls are clearly better at memory for pictures, the results for digits and geometric forms are more inconsistent. For narrative prose, the content of the material appears to be a critical factor. Women are certainly better at 'social memory' tasks such as remembering names and faces. However, men perform better on tasks of general information.

(iv) Perceptual skills

Women are generally better at tasks requiring perception of detail and frequent shifts of attention. For example, women score more highly than men on the Clerical Speed and Accuracy subtest of the Differential Aptitude Test. This subtest measures speed of response in simple perceptual tasks (such as searching for a particular pattern among a set of similar patterns). The authors of the test suggested that such a skill is important for tasks such as filing and coding; however in validation studies, clerical workers did not score any more highly than other groups. The perceptual skill at which women are superior has also been described as 'quick and accurate grasping of visual similarities and differences' or 'speed in dealing with very easy material' (Anastasi). It may be restricted to visual material.

(v) Numerical aptitudes/mathematical ability

At preschool level, either no sex differences are found or girls show a slight superiority in counting and the early development of number concepts. By primary school, however, although there is no difference, or a female superiority in computation, boys are consistently better at tests of arithmetical reasoning. Corinne Hutt has suggested a parallel between sex differences in verbal and numerical skills - i.e. that males are better at reasoning or logical manipulation of concepts or relationships, irrespective of the content (verbal or numerical) of the relationship.

(vi) Spatial, analytic and mechanical skills

These skills are grouped together here because different authors classify tasks in slightly different ways, making a clear separation of skills very difficult. For example, various spatial tests have been described either as perceptual tasks or as analytic tasks. Mechanical skills are sometimes discussed under the heading of practical tests of spatial skills, or alternatively as motor skills.

Spatial tests generally involve the ability to manipulate mentally 2-dimensional or 3-dimensional figures e.g. imagining how many times a given small figure must be used to make up a large figure, or imagining how a given figure would look if it was turned upside down or over.

Performance tests allow subjects to pick up and handle shapes in order to fit them into appropriately shaped blocks. These are similar to various mechanical tests which involve assembling objects, toys and mechanical devices, although the latter are more likely to depend on experience if familiar objects are used. (Past experience is even more important for tests of mechanical comprehension.) Although most authors claim that men perform consistently better on all these tasks, there are plenty of exceptions: for example, the difference does not develop as early as the female superiority in verbal aptitude; Gesell found no sex differences below age 5 in tests involving block building and recognition of forms. On the standardisation of the Minnesota Mechanical Aptitudes tests on 13 year olds and college students, males were better at the Assembly tests - assembling a number of common objects, such as a bottle stopper or spark plug from parts. However, on the Paper Form Board Test (described as a test of abstract spatial visualisation) males were not significantly better. Amongst the school children, girls were actually better at the Spatial Relations Test, which required insertion of numerous irregularly shaped pieces into recesses as quickly as possible. This last result has been attributed to girls' greater manual dexterity; it seems likely that perceptual speed may also be involved. However, the purpose of quoting these examples is not to analyse them in detail but to re-emphasise the need to consider the actual task involved when discussing differences in ability.

As mentioned earlier, Coltheart et al., have recently discussed the problem of 'impurity' of tasks supposedly testing a specific ability. These authors have designed two tasks - one purely verbal and one purely visual - for assessing sex differences. The verbal task involves proceeding mentally through the alphabet and counting the numbers of letters containing the sound 'ee', as rapidly as possible. The visual task involves the same procedure but this time counting the number of letters with a curve in the upper case form. The results showed that women performed more rapidly and accurately on the verbal task, while men did better on the visual task. Two further experiments suggested that during reading, phonological coding (translating visual stimuli into phoneme sequences) is more prevalent in women whereas visual coding is more common in men.

A further sex difference often related to spatial skills is that of field independence in men contrasted with field dependence in women. These concepts were introduced by Witkin who found sex differences on various tests of spatial orientation: in the 'tilted room' test, the subject sits in a tilted chair in a tilted room and has to judge when he or she is vertical, ignoring the conflicting cues from the environment. In the 'rod and frame' test, the subject sits in the dark and has to judge the verticality of a luminous rod against the tilt of a luminous rectangular frame. On both tasks men are generally better at ignoring the conflicting cues; women are more influenced by (dependent on) the environment. Performance on these tasks is often related to performance on the 'embedded figure' test, which involves identifying a simple figure which has been obscured in a more complex one.

Although it has been suggested that these tasks involve spatial perception the majority of authors include them under the heading of analytic ability, which is treated as a separate cognitive skill, irrespective of the content of the task. Thus, male superiority at analytic tasks is found in tasks involving verbal, numerical or spatial content. In particular men show a greater ability to 'break set' - i.e. to restructure a problem, or to break away from the expected way of tackling it - and also a greater facility to use relevant cues in a situation. In discussing skills of this kind it is clear that we are moving away from the assessment of specific aptitudes, into a more general area usually described as 'problem solving'.

The more 'analytic' attitude of men is said to be shown even at an early age in the sorts of questions boys and girls ask. It persists even when differences in intellectual aptitude, special knowledge and special abilities have been controlled for. For example, Sweeney (1953) found significant sex differences in problems involving difficulties in restructuring for a large sample of men and women matched on general intelligence, spatial ability, mechanical comprehension, mathematics achievement and amount of training in mathematics.

Ability to solve problems is thus clearly not determined simply by specific aptitudes. Many studies have demonstrated the influence of motivational and personality variables on performance on intellectual tasks.

For example, sex differences in motivation in relation to problem solving have been investigated. In particular it is found that male motivation is much greater: males see the solution as a challenge rather than a threat, they show a more favourable attitude towards the task and greater persistence even under conditions of stress and frustration. Girls' achievement is more related to affiliative motivation - this means that they are rewarded by praise and approval from others rather than by solving the problem.

It appears to be possible to significantly improve the performance of women by group discussions designed to change attitudes. Carey (1958) suggests that women need the stimulation provided by the atmosphere in which problem solving is encouraged, or the presence of other highly motivated persons to improve their performance.

Girls and women generally not only underachieve relative to their ability but have low self evaluations regarding their ability. They are more disrupted by failure than men, and also manifest 'fear of success', since achievement in intellectual fields is usually felt to be in conflict with feminity. Both sexes tend to evaluate a male performance more highly than the equivalent performance by a female; a good performance by a male is likely to be attributed to skill, the same performance by a female to luck.

Other personality variables have also been found to relate to intellectual performance differently for boys and girls. For example, anxiety disrupts girls much more than boys (whose performance may even be enhanced by anxiety). Conversely, impulsiveness acts as a negative factor for boys; it is less negative, or even positive for girls. Similarly, although a reasonable amount of assertiveness is needed for scholastic achievement, strong aggression impairs the abilities of boys but increases those of girls.

School achievement also depends on other factors as well as ability, although the relationship between them is different at different stages of school. In the early years of school in particular the achievement level of girls is higher than that of boys, even for equal or lower aptitudes. This has been attributed to girls' faster developmental rate, their linguistic superiority, better handwriting and greater conformity - all of which may contribute to teachers' assessments. However, it is well known that the greater achievement of women does not continue into adolescence and beyond. Women consistently underachieve relative to their ability. This suggests that external factors influence the conversion of measured intelligence/abilities into intellectual achievement, and that these factors favour boys.

<u>Relationship between specific abilities and success in science.</u>

From the discussion so far it is clear that there are sex differences in performance on certain kinds of task. In addition factors other than ability should also be considered when evaluating these performances. Before discussing the development of these ability differences it would seem to be important to consider whether any of the specific abilities mentioned are particularly relevant for success in science.

From a review of the literature it is very difficult to form a clear picture of any established relationship between specific skills and scientific achievement. For example, Anastasi concludes that 'girls are better at subjects requiring verbal abilities, memory, perceptual speed and accuracy'. However she does not specify what these subjects are. Boys, she concludes, are better at subjects requiring numerical reasoning and spatial aptitudes, as well as certain information subjects such as history, geography and science. I can't help wondering what is left for the girls to do better at! Bennett correlated scores of the various subtests of the Differential Aptitude Test with performance in various school subjects, although he acknowledges the difficulty arising from courses simply called 'science' which may vary considerably in content. He found a relationship between both general intelligence scores and numerical ability and performance in maths. For science courses, performance was predicted by general intelligence, verbal reasoning, numerical ability and grammar.

These relationships were largely confirmed by follow-up studies which showed that for male students, premedical students did better on all subtests than any other students, in particular on verbal reasoning, numerical ability, spelling and grammar; science students were also above average on all tests and particularly on numerical ability. Engineering students were above average on numerical ability - and outstanding compared with all other groups on spatial reasoning and mechanical reasoning. For women students, scientists scored highest and, in particular, they did better than average on numerical ability, verbal reasoning, arithmetical reasoning, spatial relations and particularly highly on mechanical reasoning. Note that the womens' scores were compared to female norms - which particularly for the spatial relations test and mechanical reasoning tests were much lower than for men.

Thus from the DAT studies there is no direct evidence of the impo[illegible]ance of spatial ability for non-engineering sciences. However, numerical ability was consistently associated with success in science.

On the other hand Lewis showed from a factor analytic study that numerical ability was not closely related to achievement in science. Althou[illegible] ability did correlate with achievement in physics it was not related to achieve[illegible] in either biology or chemistry.

A study of Liam Hudson's also suggested that different patterns of abilities may be related to different scientific disciplines. He compared the performance of a range of arts and science students on different sections of the AH 5 test - an intelligence test devised for discriminating between individua[illegible] the higher intelligence levels. The three sections of the test consist of [illegible]l reasoning, numerical reasoning and diagrammatic items (a form of spatial reasoning).

Arts students showed a good performance on verbal reasoning, but were poor on the numerical and diagrammatic items. Physical scientists (studying physics, engineering or mathematics) were good on the diagrammatic and numerical items but relatively weak on the verbal ones. Biologists (doing botany, zoology and medicine) were relatively strong only on the diagrammatic sections. Biochemists, chemists and metallurgists were equally strong on all three items.

I think these studies show that no clear conclusions can be drawn at this stage. This does not mean, of course, that there are no clear relationships. The studies I have read involved many different tasks to test specific abilities; some correlated this with some form of 'science achievement' test, others related it to the subject a student was studying. Further research in this area is surely possible.

Biological and socialisation factors contributing to sex differences in ability

I suggested earlier that the current debate on sex differences is developing into a sterile biology versus culture argument. Any attempt to separate biological and environmental factors or to attribute some sort of 'weighting' to each component, ignores the fact that all human development takes place in a social environment. Evidence for particular biological and social influences on specific abilities is still at an early and fairly controversial stage. I shall therefore attempt merely to sketch out the main lines of argument and evidence, in relation to differences in linguistic and spatial skills, rather than to enter into a detailed discussion of particular hypotheses.

Biological factors

The biological influences which have been invoked to account for sex differences in linguistic and spatial skills include the faster maturational development of girls, possible sex differences in brain structure and genetic and hormonal factors.

The greater verbal fluency of women may be related to their faster rate of maturation, which could give them an advantage at all phases of language development. In line with this it has been suggested that the greater frequency of language disorders in boys could be at least partially due to the use of standards that are too high for boys, resulting in frustration and confusion.

A detailed hypothesis, in terms of sex differences in brain structure, has been proposed by Buffery and Gray to account for sex differences in both spatial and linguistic ability. They argue, firstly, that there is evidence for an innate neural structure in the brain which is specific to humans and which controls speech. This is located in one half of the brain only, usually in the left hemisphere. Non-verbal skills (e.g. spatial and perceptual ones) are represented more in the right hemisphere as a result. Secondly they claim that the lateralisation of the female brain is accelerated, and that this facilitates the development of linguistic skills in women. In men the lesser lateralisation for speech means that there is a relatively bilateral representation for visuo-spatial abilities (although it is mainly right-sided) - i.e. there is less separation of linguistic and visuo-spatial skills into the left and right hemispheres. They claim further that bilateral representation is the most efficient neurological substrate for high level visuo-spatial skills leading to male superiority on such tasks.

It is important to note that this argument is based on a series of assumptions and hypotheses which are by no means universally accepted by other neuro psychologists. For example, Marshall has criticised the theory on several grounds: firstly he points out that although Buffery and Gray review data which is consistent with their hypothesis, the evidence available in this field by no means unequivocally supports their position. Secondly he suggests that more details are needed about the type of visuo-spatial tasks on which men are reputed to excel. Buffery and Gray describe them as 'tasks requiring the perception, judgement and manipulation of spatial relationships'. Marshall feels that 'manipulation' must be specified in much greater detail, which would make it possible to test the hypothesis fairly directly on both normal and brain injured subjects. Marshall concludes that the Scottish verdict 'non proven' is appropriate at the present time.

Several different lines of evidence are said to demonstrate genetic and hormonal control of spatial ability. Firstly three studies of correlations of various child-parent pairs would appear to support the hypothesis that spacial ability is inherited through a recessive sex-linked gene. (It should be noted however that the three studies used different tests of spatial ability which may involve different skills.)

Secondly, studies of individuals with Turner's syndrome (i.e. people with an abnormal chromosomal constitution XO) show that they perform poorly on tests of visuo-spatial ability. However, this finding is the opposite of that predicted from the hypothesis mentioned earlier - i.e. of transmission via a sex-linked gene. Garron (1970) concludes that although the specific hypothesis is not supported, there is evidence suggesting that the sex chromosome complement, and related sex differences in biochemical processes, may underlie sex differences in spatial and if a specific hypothesis about Turner's syndrome, as yet untested, were confirmed. However these findings are further complicated by the fact that individuals with Turner's syndrome are generally reared as females.

Evidence of the influence of the infant hormonal environment comes from studies of the effects of Kwashiorkor, a protein deficiency disease which affects the liver, which in turn results in a hormonal disturbance involving in men testicular atrophy and physical signs of feminisation such as enlargement of the breasts. The endocrinal disturbance is said to correspond broadly to that produced by administration of oestrogens. Dawson (1967) showed that West African men affected by this disease had a 'feminine' pattern of abilities (higher verbal and lower spatial score than a control group). However these results are difficult to interpret since the physical feminisation produced by the disease (which starts in infancy) means that these males are likely to have been treated differently from the control group with whom they were compared. Dawson did show an interaction between physiological and cultural variables. Men suffering from Kwashiorkor, because of their more feminine traits, were more susceptible to harsh maternal dominance, group pressures and social sanctions.

Further evidence for hormonal influences is said to come from genetically male patients suffering from 'testicular feminisation' (androgen insensitivity). These people were feminised by exposure to anti-androgenic drugs in utero. Their pattern of abilities, however, was found to depend on how they were reared: those reared as females showed the feminine pattern of abilities; those reared as males the masculine pattern.

In addition to the studies mentioned above, evidence for the biological determination of sex differences is derived from animal (especially rodent) studies. Archer has criticised arguments about hormonal influences on human behaviour which are derived from rat studies, on the grounds that there is now increasing evidence of important differences in hormonal control of behaviour between primates and rodents. Archer also points out that an emphasis on genetic and hormonal control of behaviour is generally associated with a neglect or underemphasis of the abundant evidence of socially induced influences, including a neglect of the influence of social factors on sex hormone levels (for which there is much evidence from human and animal studies).

Finally the male superiority in spatial ability has been related to finding that male rats are better at maze running than female rats. No evidence is available from other mammals. It seems to me that such evidence should be treated cautiously - in particular it is not at all clear what relationship there is between there is between the information processing carried out by a rat in a maze and that involved in a test of spatial ability for humans.

Socialisation factors

Alison Kelly has already discussed some important socialisation differences between girls and boys which are likely to contribute to the lack of girls in science. I shall focus on those factors which have been specifically related to sex differences in ability. These include differential treatment of the sexes and differences in the process of sex role development for girls and boys.

Socialisation influences on sex differences in linguistic ability include the tendency for mothers to talk more to baby girls than to baby boys, although it has been suggested that this may in part be a response to innate differences between the sexes. A few studies have also attempted to account for the greater incidence of language disorders in boys in terms of emotional insecurity or family relationships. In particular, it is noted that young boys perceive the primary school as a 'feminine' place, and enter it just at the time when they are likely to be developing a masculine sex role identity and hence experiencing a rejection of the feminine world in which they have been until that time.

Several studies show the importance of socialisation for the development of spatial ability. For example, Witkin related field dependence to dependency in interpersonal relations, suggestibility, conformity and lack of self-reliance in both sexes, and suggested that the male superiority in field independence is due to their more independent upbringing. This is supported by studies such as that of Dawson (who also looked at the effect of Kwashiorkor on spatial ability) who showed a relationship between severe socialisation and maternal dominance on the one hand and field dependence on the other.

Studies comparing the Temne of Sierra Leone with Eskimos show that whereas Temne men exert strong control over their wives and children, eskimo women and children are not treated as dependent, although they do have distinct economic and social roles. In line with Witkin's hypothesis outlined above, the Eskimos showed no sex differences on tests of field dependence; however the Temne scores were comparable with a Scottish sample and showed the usual male superiority.

It has also been shown more directly that mothers of girls who are good at spatial tasks tend to leave their children alone to solve problems by themselves. Conversely, children who are poor at such tasks have mothers who are intrusive, praise the child for performing well and criticise her for performing badly.

Field independence has also been related to the possession of masculine qualities in both sexes, or to the child's identification with his or her father. In boys a lack of spatial or analytic ability has been related to father absence, to a neglecting or passive father or to an excessive dependence on the mother.

David Lynn has attempted to account for these findings in terms of the child's development of a sex role identity. He focuses on differences in the development of boys and girls, suggesting that in our society acquiring a sex role identity requires very different learning tasks for the two sexes. The girl - at home with mother - has the easier task; she can imitate her mother, and there is no difficulty in defining the female role. For the boy, things are more difficult; he has to learn the masculine role by (in Lynn's terms)'solving a problem'. Using his father or other familiar male figures as an outline, he has to define for himself what the masculine role involves. Lynn suggests that this produces a cognitive style conducive to problem solving and field independence. For the boy without a father, the task is ...h more difficult, and he may never adequately solve the problem. Similarly a ...tal or neglecting father may cause the boy to have no wish to adopt a masculine role. This theory makes further predictions for which Lynn claims some supporting evidence . For example, boys with an 'ever-present' father should develop a 'feminine' pattern of abilities, since sex role development would involve the same 'easy' task that most girls have. On the other hand high-achieving girls are likely to have either had mothers who are more distant - perhaps employed - or to have adopted aspects of their father's role.

Conclusion

It is clear from the studies that I have reviewed that there are differences in abilities between girls and boys, in the sense that on average girls and boys perform differently on various tests. However before concluding that this provides any sort of explanation for why girls tend not to do science, several factors must be considered.

Firstly it is clear that performance on a test depends on a range of psychological factors (anxieties, expectations etc.) which interact with specific abilities. Secondly the relationship between specific abilities and success in science is not at all clear. On the one hand 'spatial ability' is said to be important for achieving in science, but on the other hand it appears that many of the tasks which are supposed to require spatial ability may be carried out by other processes. Thus while more theoretical psychological work is necessary to analyse the nature of the information processing required for a specific task, and to construct 'pure' tasks (e.g. Coltheart et al, mentioned earlier), such 'pure' tasks would seem to be even more remote from processes of scientific thinking. Finally attitudes towards science, which is seen as a masculine activity, (discussed by Milton Ormerod) may be far more important than al [illegible] r determining subject choice.

I suggested at [illegible] ing of this talk that sex differences in ability did not seem to be very relevant to the lack of girls in science. There is a danger that emphasis of these differences would lead people to conclude that only a limited number of girls will ever be capable of doing science. If we want to change the situation of girls and science then it is more productive to focus on effects of socialisation. In particular there would appear to be a clear relationship between various aspects of sex role development and both ability and other psychological characteristics related to achievement.

This discussion would seem to suggest two sorts of approach that could be pursued in the short term: firstly attempts to reduce rigid sex role stereotyping in schools and to change girls' problem solving attitudes - perhaps through discussions with teachers and pupils. Secondly attempts to change the 'masculine' image of science - school science text books might be a good place to start!

In my view more fundamental changes will be necessary in the long term, since there is, in our society at the present time, an incompatibility between being a scientist and adopting the feminine role. Only a radical change in both science and women's roles is likely to produce a significant change in the relationship between girls and science.

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SINGLE SEX AND CO-EDUCATION: AN ANALYSIS OF PUPILS' SCIENCE PREFERENCES AND CHOICES AND THEIR ATTITUDES TO OTHER ASPECTS OF SCIENCE UNDER THESE TWO SYSTEMS.

M.B. Ormerod,
Senior Lecturer and Research Tutor,
Department of Education,
Brunel University.

Single Sex and Co-education: An Analysis of Pupils' Science Preferences and Choices and Their Attitudes to Other Aspects of Science Under These Two Systems.

Summary

This paper is divided into two parts: Part A seeks to clarify and rationalize the often reported finding that girls educated in single sex schools more frequently choose to study science than do their co-educated sisters. Other influences on subject preference and choice and their interrelationships are also reported. Part B extends this analysis to various aspects of pupils' attitudes to science and their relationships to science preference and choice.

Part A.

Introduction

The writer has concentrated his own researches on pupils nearing the end of their third year of secondary education, since it is at this period that the majority of the more able pupils are obliged to make decisions regarding the school subjects they will study from the beginning of the fourth year onwards. These decisions, in effect, decide whether they will be able to pursue the study of science in the sixth form and beyond it in tertiary education. Some very able children have these decisions forced on them a year earlier still. The critical nature of these early 'choices' is attested by the Dainton Report (1968) and by a Schools Council Research Study (1973).

Nevertheless, apart from R.R. Dale, others who have reported on this topic have tended to concentrate on O and A-level data which is much more accessible. The most common observation in previous analyses has been simply that girls in single sex schools are more likely to study 'science'. Sometimes 'and mathematics' has been added to this statement. Such findings have appeared in (a) The Crowther Report (1959); (b) a paper by Sutherland (1961); (c) the DES Annual Report for 1967; (d) a very thorough analysis of the state of affairs in the sixth forms of all the schools in Gloucestershire made by that county's science advisory group in 1971; (e) R. King (1971); (f) The Schools Council Research Study (1973) and (g) Dale (1974). Whilst this paper was being written the DES has intimated (T.E.S. 24.1.75 and 4.4.75) that a report* is being prepared by HM Inspectorate carrying some disturbing conclusions about the imbalance in attitudes to various school subjects present in co-educated boys and girls.

* This report has now been published - see References.

Reports (a), (d), (e), (f) and (g) coupled the finding relating to girls with an equally significant one for unravelling the forces at work - namely that a reverse situation applied in the case of boys, i.e. that significantly less boys in single sex schools than their co-educated brothers evinced a corresponding choice of science and mathematics. When broken down into greater detail, the enhanced pre-deliction of 'single sex' girls and the reduced enthusiasm of 'single sex' boys turns out to apply only to physics and chemistry, not to biology. This was only noted in references (a), (b), (d) and (f). Dale's extensive investigations have concentrated on physics and mathematics but not chemistry or biology.

Dale, however, has devoted a tremendous amount of time to all aspects of co-education. He has, unlike the rest, used questionnaires to evaluate the liking of pupils for different subjects in the types of school involved rather than just counting heads or looking at examination entries. He has thus been able to assess the situation at two critical ages - 13 and 15. Dale's investigations have additionally covered pupils' attitudes to English literature, French, physical activities, cookery and needlework, history and scripture. Furthermore, Dale has extended his analyses to seek support or rebuttal of various explanations advanced to account for his own and previous findings - especially those concerned with physics and mathematics. Briefly the theories advanced have been:-

(i) Co-educational grammar schools in general contain pupils whose parents are on average of a somewhat lower social class than the parents of pupils in single sex grammar schools. This could certainly be an important factor in explaining the bald statement of the DES in 1967 that 'almost twice as many girls from single sex schools as from mixed schools went on to read mathematics or science at a university'.

(ii) There tend to be more co-educational selective schools in rural areas, these tend to admit a greater proportion of the age group and consequently the average I.Q. of co-educated girls is somewhat lower than that of girls educated in single sex selective schools.

(iii) In recent years the shortage of mathematics and science teachers has driven girls' schools to employ male teachers who have given additional lustre to these subjects in the eyes of girls.

(iv) Girls tend to be somewhat worse at the spatial and mechanical skills required for science and higher branches of mathematics, whilst the linguistic skills of boys tend to be inferior. Thus, when educated alongside each other, girls are likely to get discouraged in science and mathematics and boys in languages. Dale has identified the polarisation in these areas in co-educational schools and favours this explanation of it.

(v) Pupils regard almost all school subjects as either 'male' or 'female' and, when educated with the other sex in adolescence, boys and girls tend to assert their masculinity or feminity by greater predilection for subjects of their own gender and less for those of opposite gender than is the case when they are educated apart. Mathematics and 'science' have been regarded as male.

The more one attempts to unravel the causes of the actions of human beings, the more one appreciates the complexity of the motivating forces behind them. It would be imprudent to plump for any one or two of the above explanations and rule out the others, but it is justifiable to examine the evidence and conclude that any given factor could contribute to the overall situation but cannot provide a full explanation of it.

Thus, if we accept explanation (v), we are driven then to ask "What makes the physical sciences male?" Then we may have to fall back on explanations such as (iv). The point about (v) is that, whatever the origins of pupils' perceptions of the gender of a subject, it is possible that much more primordial motives are then called into play and quite obviously the co-educational situation is ideal for heightening such perceptions.

Dale (1974) analysed his data with I.Q. and social class held constant and still found greater interest among single sex educated girls in mathematics (at 15 only) and in physics, whilst the converse held for boys. Dale also found a greater interest among 'single sex' girls for arithmetic when taught by male teachers - but the reverse was true of co-educated girls! This is unlikely to be the whole explanation, however, since polarisation was widespread in co-educational sixths in 1959 when the situation was examined for the Crowther Report with a very substantial sample. The importation of male teachers into girls' schools had hardly got underway at this date. Nor does this sort of reason account for the reverse process which arises in boys' schools.

The Sample, Test Instrument and Methods.

The study was conducted with a sample of 1204 pupils at the end of their third year of secondary education (i.e. about 14+). They were drawn from 19 grammar and comprehensive schools and were all in classes which were expected to have an entry of five or more GCE subjects for each pupil at a later stage. The sample was drawn from four major geographical areas of the country:- the North, the industrial midlands, the South East and the arc of mainly agricultural counties swinging round from the South coast to the East coast. The sample contained 5 girls', 5 boys' and 5 co-educational grammar schools, 2 co-educational comprehensive schools and a few pupils from 2 single sex comprehensives.

The test instrument was the Brunel Subject Preference Grid - in which the pupil was led to produce a ranking of all the schools subjects taken by a paired comparison method. Fuller technical details for this will be published in another paper (Ormerod, 1975). The grid also allowed the pupils to indicate their degree of like or dislike for their teacher in each subject by the symbols +, ? or - (subsequently converted to ordinal scores of 3, 2 and 1). Pupils were also asked to state whether each subject would be compulsory the following year and, if not, whether they were taking it or dropping it by choice. The last two eventualities were converted to the even more crudely ordinal scores of 2 or 1. Subject preference scores were all converted to a 14 point ordinal scale, since the median number of subjects taken was 14. To get comparable measures of the magnitude of the correlations between these three grossly unequal ordinal scales of 14, 3 and 2 points the most suitable correlation co-efficient was considered to be that devised by Goodman and Kruskal (1954, 1963), termed gamma, which will be used to report all relationships in this paper.

Results

1. The single sex or co-educational situation is a significant factor in the preference and choice of both boys and girls for physics, biology and mathematics but it operates only to a slight extent with respect to chemistry in this sample.

Figure 1 sets this evidence out in graphical form. It shows the median values for subject preference on the 14 point scale for the various sub-groups. The significance of the differences in these values has been computed by the Mann-Whitney U test (Siegel, 1956). These significances are given by the italic P = .05, .01 etc. implying that the results could only have arisen by chance in 5 (.05) or one (.01) sample in 100. N.S. means that a difference is not significant. In the case of the differences in the percentages choosing a subject the significance has been calculated from the difference in the two proportions (Guilford, 1965).

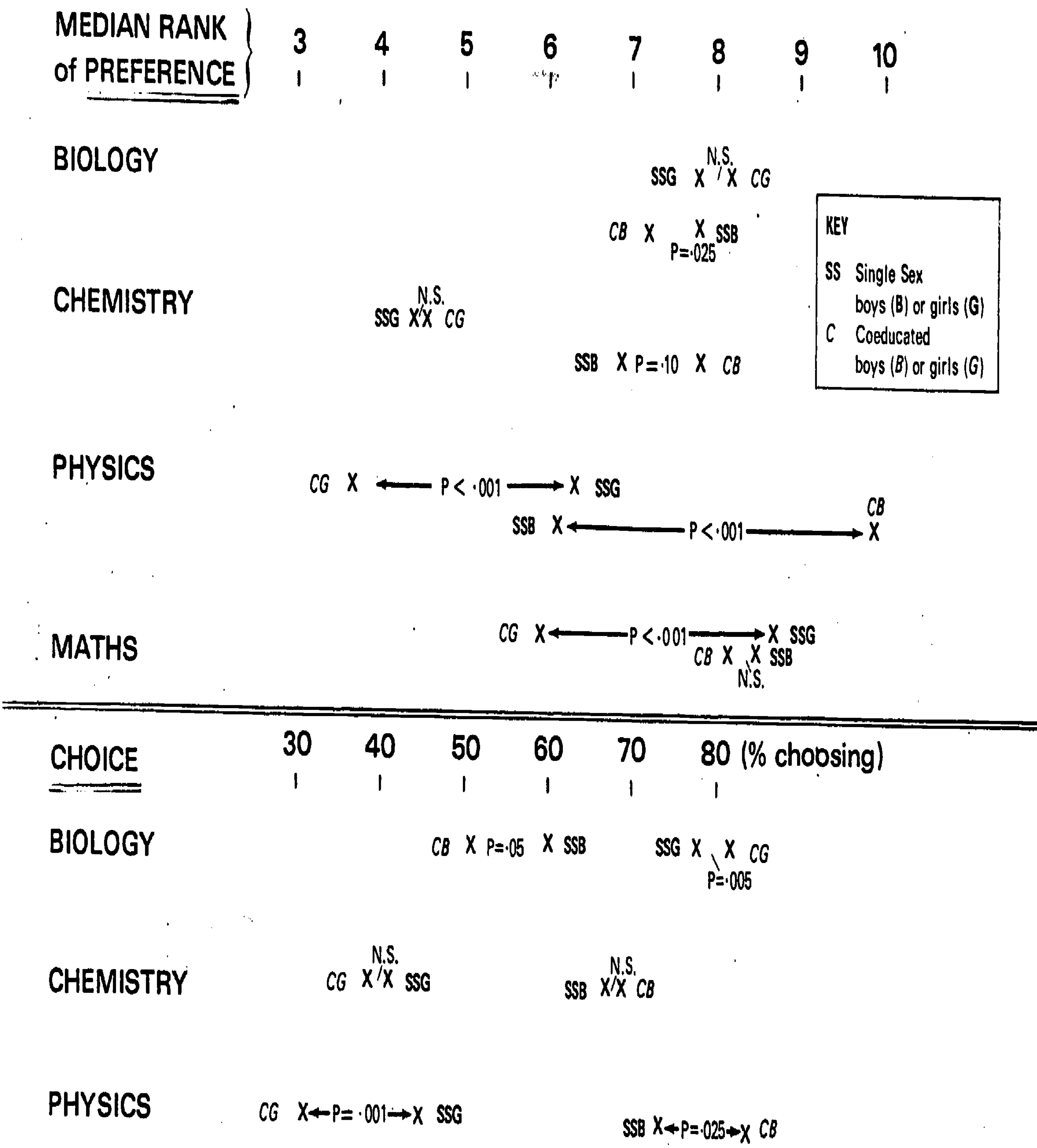
The points to note in Figure 1 are:-

(a) The values for the co-educated sexes are always furthest apart even though these boys and girls have been educated side by side! Thus co-education produces polarisation.

(b) In mathematics, physics and chemistry the co-educated boys have the highest preference and percentage choice (mathematics is virtually never a choice at this stage) and the co-educated girls exhibit the lowest corresponding values (except by an insignificant extent in chemistry).

(c) In the case of biology distinct polarisation of preference and choice is apparent

Fig 1 POLARIZATION of SCIENCE PREFERENCE AND CHOICE



but the direction of polarisation is reversed. The highest degree of preference for and choice of biology is exhibited by co-educated girls and the lowest by the co-educated boys.

(d) Finally we note that biology differs from the other three subjects in that the overall degree of preference and choice exhibited by all the girls is higher than that exhibited by all the boys, whereas the reverse is true of the other three subjects. Thus on two criteria we can label biology as 'female' and the other two sciences as 'male'. The same point comes out when an external criterion of maleness, the percentage of boys entered for the subjects at GCE O level for the whole country is examined. These figures are (DES Statistics in Education, Vol. 2, 1972):- physics, 79%; chemistry, 70%; mathematics, 61% and biology, 37%. (From these statistics, incidentally, it could be calculated that, if physics polarised to the same extent in the country as it does in this sample, all opting for physics went on to enter for it at O level, and all girls were in single sex schools, there would be 4 000 more girls entering for physics at O level - but since all the boys would be in single sex schools as well, there would be 3 000 less of them entering!)

Points (a) and (b) merely reinforce previous findings. The situation with respect to biology does not seem to have been examined quantitatively before. Its existence detracts somewhat from the 'differential ability of the sexes' explanation of polarisation but this is offset to some extent by the failure of the sexes to polarise with respect to chemistry in three out of the four situations in Figure 1. However, a paper is to be published later this year (Ormerod, 1975) in which 17 subjects in the curriculum are examined in the same way as the sciences have been treated here. This will bring stronger support to the assertion of sex identity as a powerful general factor in the overall situation.

2. Biology is the 'odd one out' among the three common school sciences.

The last two findings in the previous section support this contention. Two others emerging from this study are:-

In contrast to physics and chemistry, the correlation of preference for biology with preference for mathematics is negligible. Also the correlation of biology preference with preference for physics and for chemistry are significantly lower than the correlation of these two latter subjects with each other (Table 1).

It will further be seen from Tables 3 and 4 that the correlations of biology preference and choice with various attitudes to the social implications of science are, except in the case of single sex educated boys, too low to be

TABLE 1

INTERCORRELATIONS BETWEEN SUBJECT PREFERENCES

GCE GROUP BOYS + GIRLS

In terms of Goodman and Kruskal's GAMMA

	BIOLOGY	CHEMISTRY	MATHEMATICS	PHYSICS
BIOLOGY		16	- 01	04
CHEMISTRY			19	33
MATHEMATICS				22
PHYSICS				

N ≈ 1 000 Standard Error of Gamma ≈ .02

No sig. differences between the sexes.

Decimal points omitted

significant, whereas the correlations of chemistry and physics preference and choice are much higher and quite significant. In other words, only those boys and girls who hold favourable views about the social implications of science are inclined to like and to choose to study physics and chemistry, whereas those who like or opt for biology are neither worried about the harm 'science' may do nor necessarily optimistic about its benefits.

Quite possibly connected with this, it should be noted that there has been no 'swing' against biology to parallel that against physics and chemistry which occurred in sixth forms in the last decade and has now spread to applications for university places and postgraduate science teacher training in this decade.

Finally, Ballham (1964) and Hudson (1966) have noted that the psychological profiles of potential biologists differ from those of potential physical scientists in several respects and show more similarity to the profiles of potential arts pupils.

Findings Arisir from Teacher Liking and Subject Choice Measures

The correlations of the above with each other and with subject preference in the cases of all three sciences also throw some interesting light on problems associated with this aspect of girls' education. There are three such relationships:

Subject preference		Teacher liking
SP		TL
	Subject choice	
	SC	

Thus, for each scie... we have three relationships:

SP - TL; SP - SC; and TL - SC

The SP - TL relationship cannot be further analysed from data in this study. The other relationships SP - SC and TL - SC can be made to yield partial coefficients, i.e. coefficients in which the effect of the third variable is held constant. Thus we can derive SP - SC (TP)- the relationship of subject preference and choice when the effect of teacher liking is eliminated - or TL - SC (SP). We can aggrandize the relevant tables for all subjects, not just the sciences, and so get 'global' coefficients for these relationships across the whole spectrum of subjects for different groups e.g. sir sex or co-educated girls.

From these procedures the following findings emerge (Table 2 - see over).

3. Teacher liking is a significant moderating variable.

Its correlations with science subject preferences are considerable as are the global coefficients. Only in the case of one of our four groups - co-educated boys - the relationship significantly higher than for the other three groups we are examining.

4. So far as the sciences are concerned the relationship TL - SC is negligible except in the case of girls' biology.

Hence these are not given in Table 2. There are two possible reasons for the lack of influence of teacher liking on subject choice:

(a) either because of 'setting' or rapid staff changes, or both, pupils tend to discount teacher liking when deciding whether to take or drop a subject.

(b) choices may be made with a good deal more deliberation than the decisions which lead to a subject preference score on the Brunel Subject Preference Grid.

This means that, although crude and requiring special statistical

TABLE 2

CORRELATIONS BETWEEN SCIENCE SUBJECT PREFERENCES AND

(a) TEACHER LIKING (T.L.)

(b) SUBJECT CHOICES (S.C.)

GIRLS

	SINGLE SEX		COEDUCATED	
	SP - TL	SP - SC	SP - TL	SP - SC
BIOLOGY	54	67	36	52
CHEMISTRY	42	69	41	70
PHYSICS	48	65	48	67
GLOBAL*	45	66	44	64
N ≈	371		315	

BOYS

BIOLOGY	57	82	55	77
CHEMISTRY	54	92	41	80
PHYSICS	36	91	47	81
GLOBAL*	43	70	56	73
N ≈	293		225	

Decimal points omitted

* = Global gamma over all subjects, not just sciences

treatment, subject choice is a very robust measure of a pupils' attitude to a subject. It is only distorted by the 'setting' systems within schools, i.e. the state of affairs where a pupil either has to choose subjects A or B neither of which is particularly liked. On top of this, pupils are often advised that, if they may want to take up certain areas of study later, they will have to take this, that or the other subject. The place where this situation impinges on girls' science education is the opinion that 'all girls should do some science', which usually leads to the decision that 'they had better do biology'. Such involuntary choices show up in this investigation as negative correlations in the TL - SC relationship arising from considerable numbers who do not like the teacher 'choosing' a subject. It occurs with boys in French and Latin and it turns up, as might be expected, with girls and biology, where the SC - TL coefficient is -.28.

(This investigation also dealt with another 1 000 pupils in CSE or mixed CSE and GCE groups in comprehensive and secondary modern schools. Here the partial gamma for SC - TL in girls' physics was -.51. In this case it arose because over three quarters of the girls who liked the teacher were dropping the subject. It is pretty certain that the great majority of these physics teachers were male. Welch and Walberg (1969) have already found evidence of the potency of a variable which could be loosely termed 'masculinity of male physics teachers' as an influence on physics performance in the USA. Quite possibly it is at work here but cannot overcome the aversion of the less academic girl to physics!)

5. Both single sex and co-educated girls' science subject choices are less in accord with their subject preferences than in the case of boys.

The SP - SC relationships are a measure of how well the choices of each group match up with their inclinations as expressed by their SP score. It will be seen from the SP - SC column in Table 2 that these relationships are lower for each group of girls than they are for the corresponding group of boys. For coefficients of this size and with the numbers involved, differences of around .10 to .15 are statistically significant. It looks as though the 'single sex' boys are getting the best chances of doing what they want in the way of science options and the co-educated girls are coming off worst. When the whole curriculum is covered by the use of the 'global' coefficients it is the co-educated boys who get the best deal (gamma = .73) and the girls who are being educated alongside them (gamma = .63). With the numbers involved the difference here is significant at the .05 level.

Part B

The Influence of Attitudes to the Social Implications of Science on Pupils' Science Preferences and Choices.

Introduction

In a 'Mark I' attitude to science test (Ormerod, 1971, 1973) it was found that eight out of the twenty items separated out on factor analysis and appeared to be measuring attitudes to the social implications of science and were hence termed a 'SOCATT' scale whilst the other twelve 'SUBATT' items clearly measured attitudes to 'science' as a school subject or group of subjects. It was further found that, in the case of the girls. there was a highly significant relationship between scores on the SOCATT scale and the number of sciences taken at the end of the third year of secondary education, but that in the case of the boys no such relationship appeared to exist. The SOCATT SCALE was not 'unidimensional'. It appeared to contain at least two sorts of items.

This finding stimulated the writer to explore the 'SOCATT' dimension by assembling a bank of 49 items which contained the original 12 'Subatt' items, the original 8 'Socatt' items together with 29 more potential 'Socatt' items drawn from the writer's own item bank, the NFER Science Attitude Questionnaire (1971) and a group of items collected by Mr. I.M. Choonara for a longitudinal study of attitudes to science. These items were piloted in 1971 with 300 pupils drawn from six schools and factor analysis revealed four potential 'Socatt' scales.

Consequently this bank of items was administered at the same time as the Brunel Subject Preference Grid to all the schools who completed the latter except three, so that the sample on which this part is based comprises 1051 pupils.

Factor analysis of this more substantial data yielded the expected 'Subatt' scales and four 'Socatt' scales, whose nature is indicated below. Their reliabilities have been estimated by the method suggested by McKennell (1970). The 'Aesth' scale could be more extensively designated 'Aesthetic-Humanitarian', since it contains such items as 'Science is to blame for killing millions of people'. (And a substantial minority of pupils agree with this statement!) Respondents had to underline one of five responses: strongly agree, agree, uncertain, disagree, strongly disagree. The responses were scored in such a way that the pro-science viewpoint scored high and the anti-science viewpoint scored low.

The Brunel SOCATT Scales

Name	Example of Item	Reliability	No. of Items
SUBATT	'Science is very xciting'	.91	12
AESTH	'Science is destroying th beauti s of nature'	.88	9
PRACTICAL	'Without science w should all be living in caves'	.94	10
MONEY	'Money spent on science is well worth spending'	.81	10
SCIENTISTS	'Scientists do not think of the harm their ntions may cause'	.74	5

The validity of these scales rests on factor analytic data involving preference for other subjects and liking for their teachers. Thus, in the case of boys, liking for technical teachers has the highest loading on the 'practical' scale. Preference for art history, RI and French have significant negative loadings on the 'aesthetic-humanitarian' scale.

Results

1. In their responses pupils regard 'science' as 'male' since:

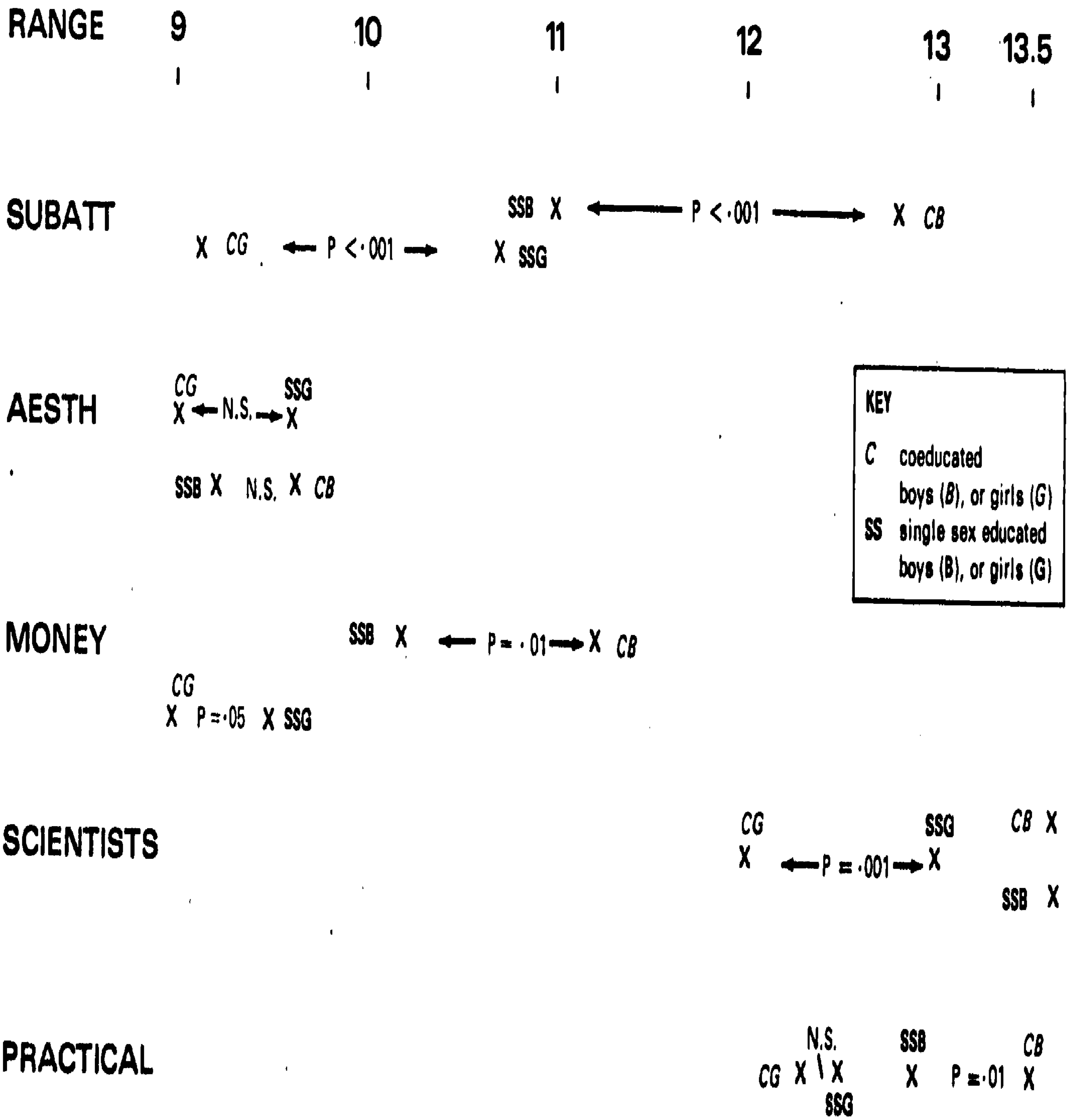
(a) The scores of boys overall are significantly higher than those of girls (Fig.2)

(b) If the scores 'polarise' in co-educational schools they do so in the ame direction as the 'male' sciences - physics and chemistry. (Fig. 2)

(c) For both sexes scores on the attitude scales all correlate significantly with preference for and choice of physics and chemistry but negligibly with respect to the same measures in the case of biology (Tables 3 and 4). Single sex-educated boys are the exception to this last finding.

The 'Aesth' scale is unique in neither polarising nor showing significant differences in the magnitude of the scores for either sex overall. This statement with respect to scores should not be confused with its correlations with other

Fig. 2. POLARIZATION of ATTITUDES TO SCIENCE



measures which do exhibit significant differences in the case of single sex educated girls and boys (Table 3).

2. There are significant positive correlations between all the 'Socatt' scores and preference for and choice of physics and chemistry for both sexes but the corresponding relationships involving biology are negligible except in the case of single sex educated boys. Tables 3 and 4)

This probably is the most important finding in this part. There appear to be at least two possible interpretations of it:

(a) only those boys and girls who tend to reject pessimistic views on the effects of science, the operations of scientists and science's value to society prefer and choose to study physics and chemistry, whilst those who prefer or choose biology are not necessarily devoid of worries about the harmful effects of 'science' or convinced of its value.

(b) those who prefer and choose physics and chemistry have a sort of positive 'gut reaction' towards 'science' and will defend it on all fronts.

Possibly both tendencies are at work. This study cannot settle this point but it is significant that there has been no swing against biology comparable with that against physics and chemistry. When considered in conjunction with the gravity of the situation arising from this swing, it would be foolish to let this finding go unheeded.

3. 'Socatt' - subject choice correlations are considerable and bring out once more the potency of the Co-educational - Single sex situation as a variable. (Table 3)

Teacher liking has not been held constant in these measures i.e. they present the situation as it stands. Two points are noteworthy:

(a) the strength of many of these relationships. Few would deny the influence of rapport with the teacher on subject preference; yet about one third of the co-efficients relating aspects of 'Socatt' to chemistry and physics choice are as great as the SP -TL relationships in Table 2. Apart from the practical value of science, which we shall see to be more important to boys, there is no mention of other social aspects of science in any official syllabus for this ability range - with the exception of SCISP. Furthermore, on account of the overloaded and conceptually difficult nature of the syllabus content and an insufficient share of the timetable, few teachers of physics and chemistry are in a position to digress into this field.

(b) the sexes are apparently influenced to different extents by different aspects of 'Socatt'. In Table 3 differences greater than 16 to 20 are statistically significant. Thus it would appear to be most important to allay the anxieties of single sex

TABLE 3

CORRELATIONS BETWEEN ATTITUDE SCORES AND

SUBJECT CHOICE (TEACHER LIKING NOT CONSTANT)

ATTITUDE - SUBJECT		SINGLE SEX		COEDUCATED	
		BOYS	GIRLS	BOYS	GIRLS
SUBATT	- Biology	40	08	07	11
	Chemistry	63	64	60	36
	Physics	76	54	72	41
AESTH/HUM	- Biology	18	06	-11	01
	Chemistry	18	43	29	23
	Physics	21	36	38	34
MONEY	- Biology	17	10	06	09
	Chemistry	36	46	53	31
	Physics	54	36	54	38
SCIENTISTS	- Biology	20	16	-03	09
	Chemistry	26	33	41	32
	Physics	35	31	54	38
PRACTICAL	- Biology	29	14	08	06
	Chemistry	15	29	49	15
	Physics	26	24	48	21

Decimal points omitted

TABLE 4

Partial Correlations between Preference for the three sciences (Subject Preference) or their Teachers and Attitudes to various aspects of Science

PARTIAL COEFICIENTS

	SUBJECT PREFERENCE (TP const)				TEACHER PREFERENCE (SP const)			
	COED		SINGLE SEX		COED		SINGLE SEX	
	B	G	B	G	B	G	B	G
SUBATT								
Biology	[illegible]	27	30	23	13	-02	-03	-04
Chemistry	35	46	44	39	12	05	15	09
Physics	36	34	45	39	25	-03	10	02
AESTH								
Biology	-03	04	21	13	02	12	14	11
Chemistry	07	15	15	28	22	18	04	[illegible]
Physics	17	11	18	22	10	13	09	04
MONEY								
Biology	06	10	25	22	-03	04	04	-07
Chemistry	18	24	24	32	13	12	09	-02
Physics	32	11	26	27	20	10	09	04
SCIENTISTS								
Biology	05	17.5	19	09	13	12	02	09
Chemistry	25	27	19	18	20	06	07	08
Physics	26	19	19	20	11	03	04	01
PRACTICAL								
Biology	06	05	14	23	-01	22	-02	-.06
Chemistry	18	20	15	21	10	15	01	02
Physics	32	13	20	25	04	03	20	03
N Biology	199	221	189	213	199	221	189	213
N Chemistry	215	234	224	212	215	234	224	212
N Physics	213	232	224	211	213	232	224	211

Decimal points omitted

educated girls about the aesthetic-humanitarian aspects of science if we want more of them to study chemistry.

Whether science gives value for money seems most important to most boys, whilst reassurance about the practical value of science and the activities of scientists is more critical for co-educated than single sex educated boys. It will be seen that it is easier to 'sell' science to the sexes separately than when they are together and there is a danger that it may be sold to one sex only in the co-educated situation.

There is an apparent conflict with the original finding (Ormerod, 1971, 1973) that social implications attitudes were only related to the number of sciences subsequently taken in the case of girls. The finding still stands with respect to the 'aesthetic' scale and single sex educated girls and boys and the original 8 item 'Socatt' scale contained four 'aesthetic', three 'money' and one 'scientist' item. The original result arose because of failure to take into account two findings of this study relating to biology, namely:

(i) The absence of any correlation between biology choice and these two Socatt scale scores in the case of all the boys.

(ii) The different way in which boys and girls go about 'choosing' the three sciences on account of their 'gender'.

Thus when girls 'choose' their sciences, the odds are heavily on biology being their first 'choice' and sometimes it is compulsory. They then can only raise their 'sciences taken' score by choosing physics or chemistry or both - choices which are correlated with Socatt scores (Table 3). With boys a reversal of the order in which the sciences are 'taken' generally applies. Boys are most likely to 'choose' chemistry and physics first. If they choose one they are very likely to choose the other and both are sometimes compulsory in boys' schools. Boys in general only raise their sciences taken score to three by choosing biology and this choice for boys overall has a negligible correlation with the 'aesthetic' and 'money' scales. There is also the possibility that pupils' anxieties about these aspects of 'Socatt' increased their doubts about taking physics and chemistry between 1970 and 1972. Public opinion polls have shown that adults' opinions about science have deteriorated in the last year or two.

4. The relationship between liking for teachers and attitudes to science is modified by the pupils' degree of liking for the subject.

Superficially it would appear from the right hand half of Table 4 that the correlations between liking for the subject teacher and attitudes are negligible.

TABLE 5

CORRELATION of ATTITUDES with TEACHER LIKING

BIOLOGY

	COEDUCATED				SINGLE SEX			
	BOYS		GIRLS		BOYS		GIRLS	
Biol. Pref.	<Me	>Me	<Me	>Me	<Me	>Me	<Me	>Me
SUBATT	10	25	-10	06	04	03	-01	04
AESTH	-17 P=.08	15	00	17	06	-13	08	27
MONEY	-05	-07	-04 P=.08	24	03	18	-05	02
SSTS	-05 P=.08	24	-10 P=.01	31	-01	18	08	16
PRACT	02	18	12	16	19 P=.08	-11	05	04
N	199		221		189		213	

CHEMISTRY

	COEDUCATED				SINGLE SEX			
	BOYS		GIRLS		BOYS		GIRLS	
Subject Pref.	<Me	>Me	<Me	>Me	<Me	>Me	<Me	>Me
SUBATT	28	10	19	15	-04 P=.02	35	05	26
AESTH.	15	08	27	02	-04	09	-12 P=.01	31
MONEY	19	13	21	04	06	12	-01	16
SSTS	22	22	23 P=.03	-10	09	05	10	16
PRACT	17	01	19	03	-15	-11	-04	18
N	215		234		224		212	

< Me = below median: > Me = above median in subject preference score

Decimal points omitted

Such a situation could arise from one of two causes:

(a) there is no correlation anyway;

(b) there are significant correlations in different sub-groups which either cancel out or become insignificant when spread over the whole group.

The latter situation appears to apply. If we split an overall group at the approximate median of their subject preference, i.e. into those who like the subject and those who do not, several correlations emerge in which there are significant differences for the two sub-groups (Table 5). The most striking example of this is the case of girls and chemistry teachers. In the case of co-educated girls, there are significant correlations between all aspects of 'Socatt' and teacher liking among those who rate chemistry below mid-way in their subject preferences. With single sex educated girls the reverse is the case! - "Varium et mutabile semper femina!" Actually male and female teacher effects may be involved but this has not been checked.

Conclusion

I must first of all apologise for the complexity of this paper. In the physical sciences, in which I was trained and originally taught, the design of investigations is relatively simple. One can usually hold constant everything but the one or two variables to be studied. Human beings are a lot more of a problem than monochromatic light or nitrobenzene, however. As the discussion of the last two findings shows it is only when all potential interacting variables in a situation are recognised, measured and their interactions analysed that a reliable picture of the situation emerges, and, even then, it is by no means a simple one.

Secondly, I do not wish to give the impression that my findings necessarily condemn co-education. It is pretty certain that if all girls were in single sex schools more of them would study the physical sciences and thereby get a more balanced education. But there are other factors to consider. It has been found, for instance, (Atherton, 1973) that pupils from co-educated schools are likely to make more stable marriages. There seems to be little chance of halting the trend towards co-education or of altering the forces within adolescent boys and girls which fuel their urge to assert their gender through subject choice in the co-educational situation. What we should be doing as a matter of urgency is looking at the sciences and the way in which they are taught to see how they can be given a more neutral image in the eyes of both sexes.

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WHAT ACTION SHOULD WE TAKE?

Jan Harding,
Principal Lecturer,
Faculty of Education and the Performing Arts,
Middlesex Polytechnic.

What Action Should We Take?

The Conference assumed, rather than argued, that the relatively small number of girls studying the physical sciences beyond the age of 13½ was a cause for concern. This was perhaps because its members were present precisely because they were concerned.

The bases of our concern.

These lie in the roles we see for science education. If we agree with Phenix, as Roy Schofield argues, that 'empirics' formalize one way of behaving as a human being, then it is important that science is not presented in such a way that girls are discouraged from participating in its study. And we can only be content with their choice of biology if we are certain that the sciences are interchangeable and equivalent in this respect.

But a further role for education (which may even be another way of expressing the first) is to begin to equip young people to live with confidence in their present and future world. This is becoming increasingly technological and in rejecting the physical sciences there is a danger that women may increase their sense of alienation from their environment and create tensions for themselves and the young children with whom they have contact (for women are still the most constant companions of young children in the home and in first schools). There is evidence, for example, that reading difficulties in boys are accentuated by young women teachers who are not prepared to use their explorations of the physical environment to develop language skills.

How one achieves these aims for science education - by the development of a highly formal system, or by children negotiating their own knowledge with the help of the teacher is, as Roy pointed out, a question of current debate.

What are the disadvantages a girl has to overcome in studying science?

Science is assumed to be a male activity.

Torrance's work, quoted by Esther Saraga, illustrates this. Liam Hudson found, when he included girls in his study of convergers and divergers and science choice that it was the divergent girl who chose to study physics and he assumed it required this self-image for a girl to act contrary to society's expectations.

Until recently the standard of laboratory provision was lower in girls' schools than in boys' or mixed schools. This has possibly contributed to the expectation (repeated recently by Mrs. Renee Short in the House of Commons in support the abolition of single sex schools) that when girls are taught in mixed schools they will do more and better science. The HMI report on 'Curricular Differences for Boys and Girls' states that they do less physical science in mixed schools. Milton Ormerod has shown us that physics is a very unpopular subject with 15+ girls in the mixed schools in his sample. Research studies, among them John Head's here, at the Centre, have shown that girls studying physical sciences at the Universities come mainly from girls' schools. But these are tending to be absorbed into mixed schools as comprehensive reorganisation continues, or may become inaccessible to many with the abolition of the direct grant. Does the environment of a girls' school insulate against the expectations of society, exposing the girls [illegible] to the expectations of the physics and chemistry teachers that they will have [illegible] to teach and that these, of course, will be made up of girls?

Science is a vocational subject.

One of the chief roles of post-13+ physical science in recent years has been vocational. This is rarely stated as an important objective for science education, but in my interviews with teachers about their use of new science curricula, one of the most powerful factors in decision-making emerged as the pupils' need of qualifications. If few women practice science it is acceptable for only a limited number of girls to choose to study the physical sciences beyond 13+.

Lack of role image with which to identify.

The limited number of women working within science confirms to girls its male image. Some physical science teachers in girls' schools are men, few physical science teachers in mixed schools are women (in 33 mixed schools I visited in 4 LEAs only one physics teacher and two chemistry teachers were women).

Girls lack experience in handling equipment.

As Alison Kelly reminded us, girls and boys are given different toys from early childhood - the boy getting the construction kit or train set, while the girl has dolls or sewing sets. Walberg, investigating attitudes of students following the Harvard Project Physics course, asked them to report how their time was spent out of school. The largest difference between the sexes occurred with activities labelled 'tinkering'. In one discussion about the use of new science curricula that I had recently with the headmistress and science staff in a large girls school, it was claimed that a 'remedial' grant was required to purchase lots of bits and pieces for girls to handle, take apart and put together, to overcome this disadvantage.

Girls display a greater fear of failure.

Recent work on the comparability of subjects at O level by the JMB have shown that physics and chemistry are 'difficult' subjects. This may have a greater effect on the liking for and choice of subject for girls than for boys, and combined with the girl's tendency to underestimate her likely success in a task may account for the frequent comment one hears in a college of education - 'I wasn't good enough to do physics'. Implied in this is the rejection of the girl by the physics department rather than vice versa.

Girls are less good at problem-solving tasks.

Esther Saraga introduced us to the interesting theory that girls develop their gender identity by merely copying the present mother, while boys achieve theirs by a problem-solving process, mainly from negative instances, in the, more common, absence of the father. Certainly girls perform on average less well than boys on problem-solving tasks under test conditions and many teachers report that girls need much reassurance, when attempting investigation-based work, that they are doing the correct thing.

It is possible that if girls 'poorer mean performance' in 'spatial' tests represents lower levels of ability in learning science, more girls than boys will find difficulties with these subjects. But if science education has more than a differentiating role to play, then the greater problems in learning science faced by girls should be a challenge to the teacher rather than the reason for girls to abandon its study.

What Changes Should We Make?

During the course of the conference it has been suggested that to bring about any significant changes in girls' involvement in science it would be necessary to change society's expectations of women, change child-rearing practices and parental attitudes, or even change the nature of science. These are massive social changes to which we may address ourselves as individuals or groups, but nearer home, as it were, are possible changes within the education system.

Choice at 13/14 years.

Alison Kelly's figures suggest that the drop-out rate of women from science at higher education levels is no greater than in other subject areas, so that the significant choices are made at 13/14 years. It was reported that the

Inspectorate had mounted a study of the English secondary school as it was emerging from comprehensive reorganisation. The effects of choice at 13/14 years will be a major focus of this enquiry.

But if we required girls to continue the study of the physical sciences in some form to 16+ this would not necessarily change their hostile attitude to these subjects in the mixed school.

School expectations.

The findings that girls in mixed schools behave differently towards science from those in girls' schools indicate strongly that the expectation of girls found within the school influences this behaviour. If the difference lay in the mere presence of peers of the opposite sex, all mixed schools should be equally affected. The personal experience of many of us indicates that this is not so. We suggest a valuable contribution to our understanding of the process of easing girls out of science would be to identify two extreme groups of mixed schools, one in which girls choose to continue to study the physical sciences in significant numbers and one in which few do so, and then to attempt to identify the factors operating to produce these different outcomes.

The role of the ASE.

The recent history of curriculum development has shown the Association for Science Education to be an influential body in bringing about change in science teachers' attitudes. The kind of science to be presented in schools continues to be problematical; a heightened awareness of the needs of girls (half the school population!) may affect decisions made about the science curriculum. We suggest it should provide a focus for discussion at a future Annual meeting.

The effects of recent developments.

It has been suggested that the use of Science 5/13 materials by girls as well as boys in the primary school may affect the attitude of girls to science later on. We need to know if this is so, or whether factors in the secondary school are over-riding. Only longitudinal studies will provide the necessary information.

Birmingham University Metereological Department has reported an increase in the numbers of female applicants since Barbara Edwards has presented the weather report on BBC 1. This indicates that an increased visibility of those women already working in science may help girls to regard it as an acceptable activity. It is encouraging that 'Tomorrow's World' occasionally includes a woman presenter for items - the media carries a heavy responsibility in image-formation. As an experiment Lanchester Polytechnic has provided week-long programmes specifically to introduce girls to the nature of engineering courses. What the long-term effect of this will be is unknown, but the idea is worth developing as a joint enterprise between schools and polytechnics in other parts of the country.

In conclusion.

It is all too easy to become overwhelmed and discouraged by the complexities of the problem of girls' science education and to feel that nothing can be done about it. I have indicated where I see further work could be done to further our understanding of the factors involved and how they operate.

One objective of the conference was to make more public the concern that many of us feel. We hope that we have achieved this and that people will continue to talk around the problem and look for ways of tackling it, and attempting some solutions, if only partial or local.