Socio-historical perspectives on the scientific education of girls in nineteenth and twentieth century England.

by

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Abstract

This thesis seeks to account for the current sex-differentiation in science education as the result of a particular social process. Unlike contemporary explanations for girls' under-achievement in science in terms of biological or social-psychological factors, this work investigates to what extent there has been in operation a "process of differentiation" which has either kept girls out of science, or offered them a limited conception of science in relation to ideas about women's role in society. It also asks how far women and girls have been excluded from, and subordinate in, the complex of activities understood as science because of male defined concerns and priorities of science, reflective of the male domination of the scientific community.

This work draws on a variety of documentary sources from the eighteenth, nineteenth and twentieth centuries to identify the significant factors involved in the shaping of science education for girls. It is argued that since the early nineteenth century science education developed in a sex-differentiated way in relation to different conceptions of the male and female spheres and to a sexually differentiated labour market. The institutional context of girls' education has also had an important effect on the determination of science education for girls.

In conclusion it is argued that the problem of girls' under-achievement in science has been seen most often as a problem for, and about, girls, rather than as a problem for, and about, science education. The socio-historical approach to the question of girls' science education suggests that an alternative view of the problem is required. This places at the centre of critical inquiry science education and the social context in which it is situated rather than the perceived negative attitudes held by girls' towards science.

Contents

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List of Tables

List of Abbreviations used in the Text

AAM	Association of Assistant Mistresses
AGM	Annual General Meeting
AHM	Association of Head Mistresses
APSSM	Association of Public School Science Masters
ASE	Association for Science Education
AST	Association of Science Teachers
AST EGM	Association of Science Teachers : Minutes of an Extraordinary General Meeting
AST EM	Association of Science Teachers : Minutes of the Executive Committee
AST GM	Association of Science Teachers : Minutes of General Meetings
ATDS	Association of Teachers of Domestic Subjects
AWST	Association of Women Science Teachers
AWST AR	Association of Women Science Teachers : Annual Report
AWST EM	Association of Women Science Teachers : Minutes of the Executive Committee
AWST GM	Association of Women Science Teachers : Minutes of the General Meetings
AWST LB GM	Association of Women Science Teachers (London Branch) : Minutes of the General Meetings
AWST SM	Association of Women Science Teachers : Minutes of a Special General Meeting
BAAS	British Association for the Advancement of Science
BAR	Annual Report of the British Association for the Advancement of Science
CACE	Central Advisory Council on Education
DES	Department of Education and Science
DSA	Department of Science and Art
EITB	Engineering Industry Training Board
EOC	Equal Opportunities Commission
FGS	Fellow of the Geological Society
FRAS	Fellow of the Royal Astronomical Society
FRSE	Fellow of the Royal Society, Edinburgh
GASAT	Girls and Science and Technology
GCE	General Certificate of Education
GIST	Girls into Science and Technology
GPDSC	Girls Public Day School Company

GPDST	Girls Public Day School Trust
HMI	His/Her Majesty's Inspector
JMB	Joint Matriculation Board
MCCE	Minutes of the Committee of Council on Education
MP	Member of Parliament
NFER	National Foundation for Educational Research
NUJMB	Northern Universities Joint Matriculation Board
RCCE	Report of the Committee of Council on Education
SIC	Schools Inquiry Commission
SMA	Science Masters Association
SPCK	Society for the Promotion of Christian Knowledge
SSEC	Secondary Schools Examination Council
SSR	(The) School Science Review
TES	(The) Times Educational Supplement
THES	(The) Times Higher Educational Supplement
WISE	Women into Science and Engineering

Introduction.

This thesis explores the development of science education for girls in nineteenth and twentieth century England. The justifications for the study are principally two-fold. Firstly, existing work in the history of science education either has ignored the significance of gender or has made only passing reference to it. Histories of science education to date have tended to deal with the general developments in science education in the nineteenth and twentieth centuries, but have made relatively little mention of the establishment of science education for girls. In the descriptions and explanations of the gradual acceptance and development of science as a school subject the class of the learners has been treated in some detail but there has been little discussion of the significance of their sex.[1] Those histories which have addressed the question of girls' education in science have done so in a way which suggests that such consideration is marginal to the development of the science curriculum. In D.M. Turner's book, for example,[2] the index has entries under "girls' schools", "girls' subjects" and "women, higher education of", without corresponding entries for boys and men. Similarly E.W. Jenkins[3] has one chapter devoted to the scientific education of girls, but little discussion of the significance of the fact that girls' science education was different to boys'. Such marginal consideration of girls' science education suggests that gender played little part in the development of school science education and the science curriculum. This thesis questions this view. Secondly, the contemporary debate on girls' science education and the discussion of girls' underachievement in science, particularly in the physical sciences, lacks a historical dimension and therefore fails to convey how and why the "girls and science"problem developed. Furthermore, it frequently fails to acknowledge the complexity of the social, political and economic factors which have contributed to girls' "failure" in science.

It is suggested here that there is a need for a study of girls' science education from an historical perspective, sensitive towards its social and political contexts. Some understanding of the ways in which, and reasons why, science education developed for girls could perhaps better inform, and place in a wider perspective, the contemporary interest in increasing the participation of girls in science. Thus, the thesis explores two broad questions. Firstly, how far has there been in operation a "process of differentiation"[4] which has either kept girls out of science, or offered them a limited conception of science? That is, how far have opportunities for girls to achieve in science been limited in relation to ideas about women's role in society? Secondly, how far have women and girls been excluded from, and subordinate in, the complex of activities understood as science - research, experimentation, the application of scientific knowledge, scientific education - because of male defined concerns and priorities of science, reflective of the male domination of the scientific community?

Theoretical approaches.

Such questions demand a different theoretical approach from those currently in operation. These generally fall either within a biological or a social-psychological perspective. It is argued here that neither of these theoretical persectives - nor the explanations which derive from them - can adequately account for the current sex-differentiation in science education.

The biological explanation for girls' underachievement in science usually rests on the finding that females show a lesser ability than males in skills associated with good performance in the physical sciences - that is, analytic and visual-spatial skills - and that this lack of ability has a genetic link. It thus concludes that females are not endowed genetically with the skills necessary for successful performance in science.[5] However, such an explanation can be contested as unsound for several reasons. Firstly, it is possible that visual-spatial ability is learned. It has been found that this ability is superior in males in adolescence and in adulthood, but not in childhood. In some cultures the sex difference in this ability is minimal or non-existent and evidence has shown that independence from early life can result in high visual-spatial ability in both sexes.[6] More recently, however, research on sex differences has been subjected to critical review and it has been suggested that "the determined differences are few, unstable and small".[7] Differences in visual-spatial ability between boys and girls which do exist cannot account for the actual imbalance of the sexes in science.[8] This fact alone should indicate that explanations which account for girls' underachivement in science solely on the basis of biology, ignore the innumerable other factors which may be in operation.[9] Following from this it is evident that biological explanations for differential achievement in science between boys and girls can be regarded as suspect and at best partial, looking to the one factor of biological sex to support the view that women's position in science (and in society) is natural and inevitable and that nothing can (or should) be done about it.[10] As Kelly has rightly pointed out, even if research does show a biological component in operation, this does not rule out positive action such as remedial classes in science and mathematics, which could compensate for girls' disadvantage.[11] However, the concentration on visual-spatial ability as a determining factor for success in science ignores the lack of agreement over what visual-spatial ability actually is, or the possibility that it is <u>not</u> a decisive factor in the comprehension of physics.[12] In short, an explanation which seeks to account for girls' underachievement in science simply on the grounds of biological differences between the sexes cannot be adequate and cannot account for the actual imbalance between the sexes in science - an imbalance which becomes more acute as the science itself becomes more advanced.[13]

Within the social-psychological perspective the socialisation process in school and society has been identified as the key factor in the formation of negative attitudes towards science education by girls. Briefly the argument is that from birth the sexes are treated differently and are expected to conform to different behaviour patterns. Boys are expected to be independent, unemotional and aggressive whilst girls are expected to be passive, nurturant, dependent and emotional; that is, boys are expected to conform to a pattern of behaviours understood as masculine, whilst girls are expected to conform to a pattern of behaviours understood as feminine.[14] In school it is argued that various processes - including teacher expectation and the selection and use of text books showing scientists as men - present science as a masculine subject and in this way girls are discouraged from its pursuit. Affirmative action in schools has generally concentrated on breaking the association between science and masculinity to enable girls to pursue its study without threatening their gender identity.[15]

Research within this perspective has been invaluable because, as Arnot[16] has noted,

> "it forces one to recognise the complexity of gender socialisation and it points to the necessity of identifying not just overt, but covert forms of discrimination within educational institutions. Second....this research also gives us an indication of the impact of gender expectations; the effect they have in terms of the self-images and academic aspirations of their pupils".[17]

However, as an explanation for gender segregation in science this approach is limited by its failure to consider "the location of the school in its socio-historical context".[18] In this way the concept of socialisation is offered as the primary reason for girls under-achievement in science without any discussion of how and why the socialisation process developed, or why school is the principal socialising agent. This tends to give the impression that gender is all-determining and that girls are a homogenous group regardless of, for example, class or racial differences. As an explanation for sex-differentiation in science education this view is also problematic because it can only explain those girls who do succeed in science in terms of deviance from the feminine stereotype.[19] Furthermore, by understanding the current stereotype of femininity as antithetical to achievement in science the tendency of this theoretical approach is to seek changes in the feminine stereotype rather than changes in science. Thus, girls are shown that they can be "feminine", attractive, married and mothers <u>and</u> successfully pursue a career in science.[20] The policy implications of this approach are that girls' attitudes are the focus for change and that girls' themselves are to blame if they fail to make the best use of the opportunities available.[21]

In seeking to account for the current sex-differentiation in science education as the result of a particular socio-historical process the theoretical approach of this work departs from these biological and social-psychological perspectives. This theoretical approach has been informed principally by the political economy perspective in the sociology of women's education, in which the central analytical concept is the sexual division of labour. This, as Arnot notes, "recognises the historical specificity of forms of gender division, inside and outside the school".[22] It also considers how "ideologies of gender, of femininity and sexuality are brought into contact....with the ideologies of class differences and class control".[23] In the attempt to understand the process of gender differentiation in science education, this approach is superior to the biological or social-psychological accounts in that it can explain the significance of both gender and class in the development of forms of science education regarded as appropriate for girls. It is an approach which is sensitive to the development of school curricula in relation to "the overall division of labour both in regard to paid employment and within the family".[24] Thus it avoids the treatment of girls as an homogenous group and calls for the investigation of girls' schooling in relation to the class position of girls. Furthermore, in its sensitivity to specific historical periods this approach can explore any changes in the form of education for girls in relation to changes in gender relations and the division of labour.

The political economy perspective is useful not only for understanding the development of an appropriate science education for girls but also for clarifying the processes by which women have been excluded from positions of power within the scientific community. Whilst this has not been a central theme of this work, the research of Rossiter[25] and Berner[26] has suggested how such processes can be analysed. Rossiter uses the concepts of "feminisation" and "masculinisation" to explain the downgrading or upgrading of status of a particular branch of science in relation to the number of women in it, the skills required and the rates of pay. Berner has analysed "the social processes behind women's marginal position in technical education and work and thus also their very limited power over technological change".[27] Using the concepts of "gender dualism", "gender segregation" and "gender subordination" she documents how women have been channeled into peripheral and powerless positions in technological education and work.

Theoretical perspectives from the sociology of knowledge and science have also been employed in the work presented here. In contrast to what Mulkay refers to as the "standard" view of science which is concerned to provide an account of the objects, processes and relationships occuring in the "real" and "objective" natural world, the sociology of science has demonstrated that "scientific knowledge is not stable in meaning, not independent of social context and not certified by the application of generally agreed procedures of verification".[28] Citing the work of Hanson and Hesse, Mulkay has demonstrated not only the theory dependency of the factual basis of science and its instability of meaning but also its social variability.[29] That is, the meaning of given factual statements may not only be in "continual flux as the interpretative context of research evolves", but also may "differ for different sections of the scientific community depending on how far these social groupings operate within divergent interpretative frameworks".[30]

In contrast to this "standard" view, both the history and sociology of science have shown the ideological elements in diverse scientific pronouncements. Mulkay, for example, refutes the normative conception of science according to which the scientific community is a cohesive body, conforming to the norms of universalism, communism, disinterestedness and organised scepticism. Instead he conceives the "norms" of science "as flexible vocabularies employed by participants in their attempt to negotiate suitable meanings for their own and others' acts in various social contexts".[31] Thus science becomes "an interpretative enterprise in the course of which the physical world is socially constructed".[32]

Similarly Shapin, writing on eighteenth century science, lays emphasis on the necessity to understand the context in which scientific accounts have been deployed in order to understand scientific judgements.[33] Rather than understanding the social use of scientific knowledge as intellectually distinct from or inferior to the knowledge itself, Shapin argues that "considerations of social use were intimately associated with the production, judgement and institutionalisation of science in the late seventeenth and eighteenth centuries".[34] This argument is developed after consideration of recent historiographical work on seventeenth and eighteenth century science in which practical social problems faced by specific groups with particular social interests have been precisely identified.[35] It is this identification of specific social groups and interests in relation to the production of scientific knowledge which is of interest here. If it can be claimed that scientific meaning is negotiated by the participants in the scientific community and that meaning can differ for persons operating within different interpretative frameworks, then it is clearly important to understand who is and who is not involved in this process of negotiation, interpretation and assessment of knowledge claims.

If it is also the case, as is widely argued, that "process, knowledge, technique and cultural context cannot be divorced from each other",[36] then it is not only important to know who is involved in the negotiation of scientific meaning, but also the cultural and social contexts in which this negotiation takes place becomes equally significant along with the specific interests of the participants.

Thus the representation of the physical world - of nature - which since the late seventeenth century has increasingly become the legitimate preserve of the natural philosophers, is intimately linked with the social group, group interests and cultural context. Thus an adequate understanding of science requires the location of participants in their cultural context in order to investigate the inclusion or exclusion of various social groups as participants in the negotiation of meaning and the representation and institutionalisation of the natural world.

This clearly has implications for any investigation concerned with the male domination of science and women's exclusion from, and subordination in, science because of its male defined concerns and priorities. Chapter two is concerned specifically with the question of women's participation in the culture of science in the early nineteenth century and the significance this had for the later development of girls' science education.

Methodology and methodological problems

Theory and method are necessarily linked. The questions asked will determine the method to be used and the information uncovered by such a method will, in turn, contribute to a refinement and reformulation of the questions asked. The history of girls' science education is a subject which has received scant attention from historians of education or science. Even the growing literature on the history of women's education has barely touched on the establishment and development of science education for girls and women. An exception here is the reasonably well documented history of the struggle by women in Britain and the United States of America to enter medical school.[37] However, even work on this subject gives little specific information on science education. With so little existing work from which to begin a study of girls' education in science there is an obvious need for a broad overview of how and why science education for girls developed. Such work which places a structure on a previously uncharted field can then act as a framework for future "in-depth" work. The method required for such a task is one that utilises, to use Hobsbawm's analogy, the telescope rather than the microscope; a method which concentrates primarily on the macrostructure rather than the microstructure[38] and is analytical rather than descriptive. Such a method involves the incorporation of the conceptual frameworks of a number of disciplines and sub-disciplines, particularly those of history and sociology - the history of science, the history of education, the sociology of knowledge and science and the sociology of education. What is required is a combination of the historian's concern with "narrative" with the sociologist's concern with "structure" to form an "historical sociology".[39]

Such an interdisciplinary approach presents its own problems. A certain degree of ambiguity is inevitably created by attempting to work in several disciplines and yet belonging uniquely to none of them. The field of women's studies, which of necessity draws on a multitude of disciplines, has made valuable progress in developing this interdisciplinary approach. It has shown how it is possible, as Spender says, to ask questions which "have often previously been 'unthinkable' and 'unthought' in single disciplines".[40]

Within women's studies a distinction is made between research "on" women and research "for" women. Research "on" women increases women's visibility, but does so in ways which simply serve to balance previous studies which have neglected to include women. By contrast, research "for" women is not simply an exercise to balance the books - adding knowledge about women to knowledge about men - but is research which takes women's experiences into account.[41] The desire to operate within this latter frame of reference creates problems when working with historical material, much of which was not written by, for, or even specifically about women. However, in many cases such material is all that is available and it can be valuable if it is reinterpreted and understood in the light of its specific social context.[42]

For this study information was culled from a variety of documentary sources: official publications, journals, text-books, books, biographies, autobiographies, minutes of various professional associations and association reports. There are particular methodological problems associated with documentary research in that only those events, statements or ideas which were regarded as important or significant by the author, get selected for inclusion. However, by understanding the documents in relation to their specific social contexts it is possible to make sense of the selective criteria of authors and to judge the significance of what was included and excluded. More problematic is filling the gaps which documentary research presents. Not all social groups had the same access to the written word, or to the means of recording their lives. This point is particularly relevant to research which concerns women. Diaries, journals, letters, books all tended to be the preserve of middle and upper class women. Very little material is available which details the lives, thoughts and feelings of working-class women, except as perceived by other social groups. This has been a particular problem in the work presented here. In the absence of documents written by women it has been difficult not to treat them, particularly working-class girls and women, as passive recipients of decisions made from above. In this, as in all aspects of the research, the available material, by necessity, has shaped the inquiry. For example prosopographical studies of women scientists and women science teachers were considerably hampered by the scarcity of biographical information on such women. More fruitful was a study of the work of women science writers and of the records of the Association of Women Science Teachers now deposited in the Brotherton Library at the University of Leeds.

As well as understanding the specific social contexts in which documents are written, women's history also requires redefinition of some of the categories of historical analyses.[43] For example, in conventional histories of science women are generally absent - with a few notable exceptions - because they have not been at the forefront of the development of scientific knowledge. In trying to understand how and why science education was established for girls it is both necessary to consider what is meant by science in order that alternative definitions do not get missed out of account, and also why a particular conception of science, in which women were, and are, noticeably absent, became dominant. In this work a broad definition of science has been utilised encompassing subjects like hygiene and domestic economy as well as physics, chemistry and biology. The focus of attention however is on how science was defined <u>for</u> girls, rather than how girls or women defined science. By this means it is hoped to illustrate the status differences which have developed between the various branches of science and how low-status science tends to be defined as "women's science".

Any historical research has the problem of knowing what temporal limits to set for itself. The time-span of this work was deliberately chosen to encompass important changes in the social structure of science, the establishment of formal educational provision and significant changes in the social role of women. In the absence of previous work, it was thought important to consider this broad historical period, charting events at the level of intentions for the scientific education of girls and the social factors involved in the shaping of these intentions. One consequence of this decision is that the research does not address in any detail the experience of science education at the level of the classroom and school laboratory. The methodological problems associated with the reconstruction of "classroom reality" in the past are, in any case, formidable. In the absence of a general map of the territory, judgements about the limited periods in which in-depth investigation into the scientific education of girls might more profitably be made were deemed premature.

The point of departure for this thesis is that the sex-differentiation of contemporary science education is a matter for concern and one which should not be ignored. In what follows I first attempt to identify the various interests involved in the contemporary discussions on girls' science education and to draw out some of the competing explanations for the dearth of girls in science and the competing definitions of the problem. This serves both to review the current literature and to show the failure to date to view the "girls and science" problem in its historical and social contexts. The following chapter (2) examines the possibilities for women in science prior to its development as a professional pursuit. I argue that women, especially middle class women, were an interested and active but marginal and increasingly marginalised group. This marginality had important consequences for the dominant definition of science and for the later establishment of science education for girls. In the next two chapters (3 and 4) I investigate the institutionalisation of school science education within formal schooling in the nineteenth century. Chapter three looks at the definition of science deemed appropriate for girls as this emerged in working class education, while chapter four looks at the possible constructions of science education for middle class girls. Chapter five carries both these developments through into the early twentieth century in order to investigate the failure of the movement for domestic science to replace the traditional science curriculum for girls; it also examines what implications this had for the future development of girls' science education. Chapter six, also concerned with the twentieth century, explores a new vein of evidence; it looks at the major association of women science teachers and how far, in what ways, and why, they had conceptions of science education for girls alternative to those which were being developed by other interest groups over this period. The concluding chapter assesses the value of a socio-historical approach for contemporary concerns about the scientific education of girls.

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Ratio of men to every one woman.	In all subjects.	In science.	In engineering and technology.
A-level (college)	1.3 / 1	2.8 / 1	-
Undergraduate	1.8 / 1	2.4 / 1	24.0 / 1
Post-graduate	2.8 / 1	5.0 / 1	19.5 / 1

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19. ibid., p.105; see also Scott, S., "Holding on to what we've won", Trouble and Strife, no.1, Nov. 1983, p.25, for a critical discussion of socialisation theory.

20. This has been the approach of much of the policy concerned with the question of "girls and science" since the 1950s. For a discussion of this, see, Arnot, op.cit., pp.100-102.
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1. The "problem" of women and science and the scientific education of girls.

It is a well documented fact that, in the western world, girls and women are significantly under-represented in the physical sciences, both in the education system and within the scientific professions, including science teaching[1]. As long ago as 1869 Lydia Becker posed the question, "Why do students of science among men greatly outnumber those among women?"[2] At the time when she was writing, the availability of science education for all could by no means be taken for granted; furthermore, science itself had not yet become a fully professional activity.[3] It is only during the last few decades of the twentieth century, since the close of the 1939-1945 war, that the same question has elicited official recognition of a problem and has become an urgent consideration for women.

From the discussion and work published on the question of girls and science education, three distinct, though not unrelated perceptions of the problem are evident. The first, which may be called the state or managerial view, sees the intellectual potential of girls as a significant untapped resource for scientific and technological labour power. At various times since the 1950s government ministers and industrialists have urged more girls to choose science as a matter of national importance to ensure that there is an adequate supply of scientific and technological personnel. It is arguable that concern about the dearth of girls choosing science, from this perspective, is limited to periods when there is a shortage of skilled men to fill the gaps in the labour market or when it is perceived that skills required can be better provided by women than by men[4].

The second perspective approaches the problem as one of equality of opportunity and seeks to identify and reform those factors believed to be working against the achievement of girls in science. This perspective is the one most visible in science education, espoused both by all those seeking equality between women and men and by science educators who regard girls' early rejection of science as detrimental to their general education. Concern within this perspective has tended to be expressed in terms of what Keller[5] has called the "liberal feminist critique of science". Broadly this argues that the problem with science education and the professions, with regard to the entry of girls, is not its subject matter, nor methodology, but its inegalitarian organisation. In short it is stated that existing barriers to girls' entry into science education need to be removed. A more radical version of this suggests that the research priorities of science (and hence the science curriculum) reflect the male bias of the scientific community, and, that with more women in science the projects and priorities of science would be different.

The third perspective views the incidence of the under-representation of girls and women in science as one aspect of female oppression within a patriarchal[6] system of domination. In this view, the belief that scientific method is value-neutral and scientific production is independent of social interests is strongly challenged. Following from the radical critique of science which sees contemporary Western science as a product of a capitalist system, this view argues that the methodology and practices of science are inherently masculine. As such, there is little hope that any significant changes can be brought about simply by more women entering the field. Rather, any significant entry of women into science will be premised upon the transformation of its methodology as well as its organisational practices. The nature of this transformation is not clear, but it is implied that it will involve replacing within the range of scientific activities women's values and experiences which have systematically been denied throughout the recent history of science. In what follows I intend to discuss each of these three perspectives in more detail, both in order to clarify the contemporary debate on girls' science education and to introduce the main themes for the thesis.

The demands of state and industry

In the decades following the 1939-1945 War science and technology were identified as the key to Britain's industrial progress, national strength and prosperity. In 1956, for example, Prime Minister Sir Anthony Eden declared:

> "The prizes will not go to the countries with the largest population. Those with the best systems of education will win. Science and technical skill give a dozen men the power to do as much as thousands did fifty years ago.

> Our scientists are doing brilliant work. But if we are to make full use of what we are learning, we shall need more scientists, engineers and technicians. I am determined that this shortage shall be made good."[7]

These sentiments were echoed in Harold Wilson's four-fold programme of action to herald the "white-hot technological revolution" of the 1960s[8] and in recent government policy for science and technology[9]. A major concern of government policy has thus been one of ensuring an adequate supply of skilled scientific and technological personnel; girls and women have been, and continue to be, identified as an important source of recruitment. Since the publication in 1956 of a government white paper on technical education which set out plans for increasing the number of students continuing education in the scientific and technical fields[10], statements concerning girls education or women's entry into scientific careers have repeatedly described the situation in terms of "an untapped pool of ability" or a "waste of women".[11]

Whilst differences of emphasis on the importance of science education for girls have been apparent at various times in the last few decades, the "problem" of girls and science in this perspective of state and industry has for the most part been simply one aspect of the much wider concern with scientific manpower. Thus, Mark Carlisle, Secretary of State for Education and Science, could say in 1981 that the reasons why the Government wanted to encourage girls to study the physical sciences and craft, design, technology and engineering were "not entirely altruistic and to do with their personal development". He went on to say, "At the moment there is a huge waste of the nation's resources because a large proportion of our young people are ruling out careers in the productive sectors of our economy".[12]

Overall, the late 1950s and early 1960s were years in which science, engineering and technology gained ground in secondary and higher education for reasons identified as "the promise of discovery, progress and excitement associated with science courses", "the prestige of obtaining a university place in science or technology" and "the emphasis in statements of public policy on the shortage of engineers and scientists with consequent prospects of better careers in those subjects".[13] In sixth forms there was a growing preference for specialising in science and mathematics[14], and it was feared that the demand for places in higher education would exceed their availability, with the consequent recommendations of the Robbins Committee for the expansion of higher education.[15] However, in spite of all exhortation to girls to elect for science courses, by 1962 the proportion of girls attempting science in the sixth form remained much the same as it had done for the last ten years, if not actually decreasing[16]. It was also clear that the demand for women's labour in science was of a particular kind in the service jobs of science: as technicians[17], in research rather than production[18] and most of all as teachers[19]. Industry was most reluctant to employ women on the same terms as men[20] and the demographic shift towards earlier marriage and fewer single women in the population than in the preceding century[21] meant that the demand for women's labour during these years was situated firmly within an existing sexual division of labour whereby women were expected to fulfil home and family duties as well as enter the workforce[22]. Indeed the vast increase in the number of working married women performing a "dual-role" in the late 1950s was a sufficiently new phenomenon to bring forth considerable sociological research[23].

By the late 1960s these issues had receded in a new concern over the "swing from science" in school and further and higher education, which had been perceived as early as 1963[24]. Girls' antipathy to science was once more perceived as compounding an already serious problem, and the new fear was "that the Robbins' concept of equal university expansion for arts and science now seems likely to founder on a chronic relative shortage of science applicants".[25] In the '50s the problem had been one of the shortage of places in higher education for those school science students who wished to take further courses in science. However, soon after the Robbins programme of university expansion was underway this situation was reversed - the problem then became one of how to recruit new students.[26] As a school subject science not only had to compete with the Arts side, but also with the increasingly popular social sciences.[27] The brief, post-war popularity of science and technology had given way to strong anti-science sentiments engendered in response to the Vietnam war, environmental pollution and the development of nuclear, chemical and biological weapons. Significant popular movements had emerged in the 1960s as manifestations of these sentiments.[28]

In order to improve the uptake of science among the school population as a whole the response by industry and government was to inject funds into school science projects sponsored by bodies such as the Nuffield Foundation[29] and the Schools Council[30]. Although the aim was to produce curricula which met the needs of the individual pupil[31], little development was aimed specifically at girls, with the exception of one conference sponsored by the Schools Council and the Women's Engineering Society on "Science and Technology for Girls", held at Warwick University[32], which looked at how the Schools Council Project Technology was received by girls. However, there was still concern that the biggest single source of engineers remained untapped. Public money was used to launch "Women in Engineering Year" in 1969, by the Labour administration. The aim here was largely to increase the number of women in the engineering professions: the effort was aided by one million pounds from the Department of Education and Science and the Ministry of Technology.[33] In spite of this, judging by the dearth of media coverage of this initiative, it would seem that it achieved little.

More recently, fuelled by a recognition of skill shortages in engineering, public and industrial funds have been used for several affirmative action projects designed to improve the uptake by girls of science and technology courses in schools and colleges. Beginning in 1980, the Engineering Industry Training Board ran week long "Insight" Courses for sixth form girls, to inform them about engineering as a career and to persuade them to study engineering at university or college.[34] The Manpower Services Commission financed a £23,000 project to help women engineers who wished to return to work after having children, and at least one polytechnic received money from the Inner London Education Authority to create a new woman's teaching post in engineering.[35] Between 1979 and 1983 the Social Science Research Council approved a grant for an affirmative action project to improve the science achievement of school girls[36]. In 1984 a national initiative sponsored by the Equal Opportunities Commission and the Engineering Council - "Women into Science and Engineering Year" (WISE) - was launched. Its stated concerns echoed those of the previous decades, concentrating on skill shortages and national prosperity.[37]

The scientific profession also began to take an active interest in the question of girls and science. In the 1960s, the concern was with the state of science education and the flow of new recruits. The professional scientific institutes responded by establishing their own journals aimed at improving the teaching of the different science specialisms at all levels.[38] In the 1980s, the response by some branches of the profession to the "girls and science" question was to produce further reports[39] and to run courses similar to those run by the engineering industry.[40]

Whilst the motivation for this interest in science education since the 1950s can be shown to be primarily economic, some "official discourse"[41] promoted "science for all" and curricular reforms for humanistic and educational reasons. Thus the Dainton Report of 1968, for example, preceded all "manpower" concerns with those of the "potentially harmful" effects on both the individual and society of "the relative decline in the study of science and technology". The increasing incursion of science and technology into everyday life meant that "those who have no scientific understanding are cut off from a great human activity; and may well feel excluded from intercourse with those who have such understanding".[42] Recent ministerial statements have in this way suggested that girls' rejection of science not only handicaps them in their opportunities for employment and in aspects of every day life which require a group of mathematical and scientific concepts, but also denies their chances of reaching their "full potential".[43]

This "official discourse" echoes what has been the dominant rationale for science education throughout its recent history. The study of science, it has been argued, can "develop processes of thought and forms of behaviour which are both desirable in themselves and transferable to other situations".[44] That is, it has been, and continues to be, argued that science education is an important component of general education which seeks to develop the intellect. However, as much as science educators may subscribe to this view, investigations of the content of school science curricula reveal their persistent bias towards the needs of future specialists.[45] Furthermore, the desire for a scientifically literate population, evident since the 1950s in ministerial statements[46], can be interpreted both as a means of ensuring an adequate supply of labour competent to deal with technological surroundings and as a form of social control.[47] Even the recent development of some science and society courses can be understood as educational reform which will lead to the acceptance of controversial technology and a belief in the legitimacy of scientific decision-making institutions.[48]

In short, interest in the dearth of girls choosing science since the late 1950s from the perspective of government and industry has primarily been stimulated by concerns over shortages of skilled scientific and technological personnel. The more recent willingness to support research investigating girls' under-achievement in science or other initiatives which aim to increase the number of girls choosing science courses in the present economic context, can still be interpreted largely in terms of a "manpower" perspective. In spite of other claims made for science education, within this perspective, the problem and its solution is conceived simply in terms of numbers of qualified personnel.

Equality of Opportunity

The argument from this perspective is based on the belief that a "basic knowledge and understanding of science is both desirable and necessary for all pupils, and that present arrangements are failing many girls in this respect" (my emphasis).[49] This view suggests that lack of education in science for girls denies them entry into one of the "fundamentally distinct ways of perceiving the world, to which every complete individual should have access".[50] However, on a more practical level it is asserted here that girls need education in science both for access to jobs in the scientific and technological fields, and for access via the scientific professions to social power and control over their lives in a world increasingly dominated by science and technology.

It was clear by the mid-1970s that women's position in the scientific professions had not improved since the 1950s and may even have worsened since the early decades of the century.[51] As Kelly noted in 1974[52], women in science were still not socially acceptable, and the bias of secondary education in science was towards boys both in provision of courses and the content of the curriculum.

As noted above, little research had been done before this time to investigate why girls opted out of science in school. The tendency was to assume that girls were too interested in marriage to continue at school[53] or that parents and employers discouraged girls from going into traditionally male professions. A few isolated articles did touch on the processes within and outside school which acted as negative influences on girls' science choice[54], but as one writer noted, in highlighting sexually differentiated toys and the importance of early play experience in forming positive attitudes towards science and technology,

> "Perhaps the present generation of parents will find it too difficult to treat their small sons and daughters as equally receptive beings, and it will have to remain for the next generation of more scientifically minded parents to arrange a new mental climate for the very young".[55]

Calls for affirmative action to enable more girls to take up science, such as conversion courses in the first year of university[56], and for flexible working hours for married women with children[57], went largely unheeded.

By contrast, the context of the early 1970s was favourable for the emergence of the question of the scientific education of girls from a women's perspective. The new wave of feminism which had arisen in the 1960s began to be consolidated at the end of the decade by women demanding equal civil rights, such as equal pay and employment and also by women beginning to analyse the mechanisms by which they were oppressed - socially, institutionally, culturally. Certain victories were won, such as the Equal Pay Act of 1970, the free provision of birth control in 1974 and the Sex Discrimination Act of 1975, with the subsequent establishment of the Equal Opportunities Commission[58].

The atmosphere of equality of these years undoubtedly ensured that research into the mechanisms operating in school by which girls were disadvantaged in science could not be so easily ignored as previously. This was particularly so after the 1975 legislation, which made it an offence to discriminate on the grounds of sex[59].

In 1975 an education survey[60] clearly demonstrated that at the stage when option choices had to be made, fewer girls than boys were <u>offered</u> courses in physics and chemistry; even fewer girls compared with boys chose such courses and an even smaller proportion of girls compared with boys took examination courses in these subjects. In biology the situation was reversed[61]. Jan Harding, through her work on the Curriculum Diffusion Research Project at Chelsea College, University of London, reported in 1975 that the approach to science embodied in the Nuffield Projects and the examination methods employed, appeared to be turning girls away from science[62]. A project, supported by the Nuffield Foundation, was set up to investigate this further[63], and the question of girls' under-achievement in science was thrown open at a conference held at Chelsea College in 1975.[64]

The conference considered why physical science continued to be limited in the education of girls and whether this should give cause for concern. That it was a cause for concern was assumed by the participants on the basis that girls needed physical science as much as boys to enable greater career choices, a greater sense of control over their social environment and, perhaps most importantly, because science was a particular and distinct form of knowledge which should not be absent from a balanced education.[65]

The conference noted several disadvantages facing girls when it came to science education. Science, it was argued, was assumed by girls to be a male activity and only those girls prepared to act contrary to society's expectations of them chose to study physics. It was also noted here that girls who studied the physical sciences at university tended to come from all girls' rather than mixed schools, in spite of often poorer laboratory provision in the former. This raised the question, "Does the environment of a girls' school insulate against the expectations of society, exposing girls more to the expectations of physics and chemistry teachers that they will have classes to teach and that these, of course, will be made up of girls?"[66]. Another factor discussed was the male vocational associations of the physical sciences. This became especially important at a time when options were chosen and thus, "if few women practice science it is acceptable for only a limited number of girls to choose to study the physical sciences beyond 13+".[67]

A further area in which disadvantage was located was that connected with the skills required of science students. It was argued here that because of different early play experiences of boys and girls, girls were less well prepared to handle equipment. This could well contribute to another disadvantage faced by girls, namely their fear of failure was greater than that of boys. It was suggested that this led them to reject physics and chemistry because these subjects were perceived as "difficult".[68] Another point discussed here was that girls had been found to be less good at problem solving tasks; teachers reported that girls needed much more reassurance that they were doing the correct thing.[69] This lack of practical skill and of confidence on the part of girls was suggested as the reason for being allowed to give up the study of physics and chemistry. However, a more positive approach, it was suggested, would be to regard as a pedagogical challenge the greater problems which girls faced in learning science.[70]

Considering practical solutions to the problems identified at the conference, it was noted that the under-representation of girls in science education was not a problem related solely to the education system, but was one which had its roots in the social place and expectations of women, in childrearing practices and even in "the nature of science"[71]. However, optimism was expressed that whilst science educators could not induce the required massive social changes, it was in their power to influence aspects of the educational system which discouraged girls from choosing and succeeding in science. In making these points in her summary of the conference, Harding, in effect, set the agenda for future educational research in this field: the age at which options were chosen and whether compulsory science would improve the situation; the influence of single sex or mixed schools; the influence of the primary school; the influence of role models and images of science.[72] It was also noted that there was a possible role for the Association of Science Education in terms of curriculum developments which took into account girls' needs.[73]

It is evident that this conference was one of the first steps taken to place "girls and science" firmly on the educational agenda. In the years immediately following, research was very much restricted to those individuals with particular interest in the subject and who were situated in institutions which enabled them to do such research. Harding, for example, unable to get funds to develop further the Girls and Science Education project[74], continued her work on sex differences in examination performance in science, showing that co-education and forms of assessment such as the multiple choice paper have been negative influences on girls' achievement in science.[75]

In an attempt to bring together the various researches which had been carried out on the question of girls and science in the 1970s Kelly edited a collection of "theoretical essays, research studies and personal accounts" which were concerned to "elucidate the origins of girls' under-achievement in science and suggest ways to improve their performance".[76] In this work and other work appearing at a similar time at least four sets of processes were shown to operate both within school and society in ways which discouraged girls from studying science.

First there was the organisation of school, including considerations such as the structure of option schemes, timetabling and the availability of various subjects.[77] Second was the influence of teaching approaches and the science curriculum including the subject content of the curriculum which traditionally drew upon skills which boys were more likely to have acquired in their earlier play[78]; text-books which portrayed scientists as men and, in which if women were pictured at all, they appeared in domestic and service roles[79]; examination syllabuses and the design of examination questions[80]; the lack of their involvement in science lessons because of teachers attitudes towards girls[81]; and the small proportion of physical science teachers who were women - a situation which helped to reinforce the notion that physical science was a subject for boys[82]. Third, parental attitudes and careers advice could have negative and discouraging effects upon girls when they tried to opt for subjects which were outside "traditional" women's areas[83]. Also, careers advice might leave girls ignorant of the need for science in future occupations[84]. Finally, the fourth set of processes related to the pupils' beliefs and attitudes about the subject. Science was found to have a strong masculine image which significantly shaped the way in which girls and boys perceived it[85]. The stereotypical personality traits of scientists had been shown to stress impersonality, high ability and detachment[86] and these traits were fundamentally at odds with those of the stereotypical female[87]. Options to study or not to study science occurred just at a time when children experienced puberty - a time when gender conceptions were being consolidated and one view suggested that subject choice reinforced the newly developing gender identity[88].

Research of this nature has been used to inform various intervention strategies. The Girls Into Science and Technology (G.I.S.T.) project[89] which ran from 1979-1983, funded by the Social Science Research Council, is one example. At school level some teachers devised their own strategies to increase the participation of girls in science. For example, at Bedfords Park School, Essex, a group of science teachers devised practical measures to encourage girls to opt for physical science. When planning the syllabus, topics which more girls than boys found difficult or uninteresting were modified and extra encouragement was given to girls to ask questions and to contribute to activities in the laboratories[90].

Importantly, these strategies and the research which has informed them have tended to define the girls and science "problem" in a particular way. Thus, the problem is perceived as that of the low take-up of physical science by girls and of their underachievement in science. It is a problem to which solutions can be found by manipulating the school environment to make it more favourable to girls and the content of the school science curriculum in order to appeal to "girls' interests"[91]. Indeed, one H.M.I. Report was specifically devoted to discovering what help and support schools could give to aid girls overcome learning difficulties in science[92], and reported on the various factors which were felt to have most influence on girls' pattern of choice in science - social and environmental influences; career choice and school guidance; teaching approaches and the school curriculum, and finally, resources.

This definition of the problem and the action which springs from it may well assume greater importance in the future because of the renewed state concern for more scientists and technologists noted above and, equally important, because of a certain level of public commitment to equality of opportunity in education for the sexes. As one researcher in the field has put it, in terms of the underachievement of girls in science being understood as a problem which should not be ignored, "the battle of minds has been won"[93]. Whereas in the "Great Debate" of the late seventies no mention was made of girls and science[94], the discrepancy between education in science for girls and boys was noted in the H.M.I. Survey on Secondary Education in England[95] and is unlikely to be ignored in the School Science Curriculum Review[96], which is examining the form and content of the science curriculum for all young people[97].

Whilst these developments can only be applauded, it should also be noted that there are limitations and dangers in defining the problem of girls and science essentially as one of "learning difficulties" or "underachievement". In the final analysis, even though explanations may look to the social sphere and oppressive social structures, the emphasis on achievement and underachievement directs attention towards the negative attitudes towards science held by low achievers. In consequence effort is directed at changing girls' attitudes or modifying the science curriculum so that it corresponds with positive attitudes which girls may have. For example, Simonis notes that

> "Junior high students in general and young women in particular seem keenly interested in environmental sciences and in practical technology in making connections to the real world around them",

she thus concludes,

> "that integration of social sciences, environmental studies, and biology, the 'softer' end of the science spectrum, is appropriate and likely to better meet the needs and interests of girls 12 - 14 years old, than do traditional physical science courses."[98]

Not only does such a strategy, aimed specifically at girls, become questionable in terms of reinforcing existing stereotypes and pre-defining what girls' interests are, the consequences of implementing such a scheme could lead to a "ghetto-like" low status science for girls[99]. Furthermore, it could fail to enable girls to understand the "form of knowledge" represented by the physical sciences, - and this was one of the motivations behind the initial concern.

There are also limitations in conceptualising the problem principally as one of access and equality of opportunity, and, in consequence, directing positive action towards removing barriers to achievement. Whilst the barriers of discrimination, bad time-tabling, biased option schemes and so on may indeed need removing, this may not, in itself, produce a great influx of new, female science students. However, having conceptualised the problem simply in terms of the proposition that "if barriers were removed then more girls would do science", if intervention strategies aimed at removing barriers fail to increase significantly the number of girls choosing science[100], the way is open for girls to be blamed for their own underachievement in science. The suggestion could be made that girls are "naturally" weak in science or "naturally" interested in other subjects.

These points have not gone unrecognised in the science education world. At a recent international conference on the theme of Girls and Science and Technology (G.A.S.A.T.) some of the contradictions in approaches were noted, not least the fact that

> "Most participants agreed that we are talking about an aspect of women's oppression (when considering the problem of girls and science). But it was recognised that most of the strategies we use operate as though it were a question of inequality which can be solved by good will and education".[101]

Again, on the question of whether science and technology should be taught in single-sex groups, it was noted that not only would this be illegal in some countries, but, perhaps more dangerously,

> "it was felt that schools might turn to single sex groupings for the wrong reasons, and that girls' groups might be davalued just because they were girls."[102]

More important here would be

> "Training teachers to ensure equality between the sexes in mixed classrooms".[103]

New directions are now being explored in the science education field. The G.A.S.A.T. conference, bringing together science teachers, teacher trainers, education lecturers and researchers, felt that changes were needed not only in girls, but also in boys, in school science, in science and in society. More specifically, much interest was shown in classroom interaction studies, which although still rudimentary, were beginning to show how boys established and maintained their dominance in science classes, and how teachers responded differently to boys and to girls.[104]

On a more theoretical level, the work of Chodorow[105] and Gilligan[106] has been influential in suggesting new areas for inquiry.[107] Both turn to psychoanalytic accounts of earliest human experiences to explain basic gender divisions in human characteristics - why, for example, men seem to be more assertive and individualistic, whereas women tend to be more emotional and to relate on a closer, interpersonal level, and why therefore, masculinity is associated with objectivity, rationality and lack of emotion, whereas femininity is associated with subjectivity, intuition and emotion.

Chodorow uses object-relations theory, which takes as its starting point the belief, "that the childs' social-relational experience from earliest infancy is determining for psychological growth and personality formation".[108] Drawing on classical Freudian theory, she argues that the successful development of heterosexual orientation in boys depends on the primary love object - the mother, being replaced by the father. That is, boys achieve masculinity by denying in them all that is represented as feminine in the mother. For girls no such change of love object is required and instead a girl maintains attachment to her mother as well as to her father. A girl may turn to her father, but this is not at the expense of her mother.[109]

The importance of these early social relational experiences is that relationships are experienced differently by men and women. As Gilligan notes,

> "For boys and men, separation and individuation are critically tied to gender identity since separation from the mother is essential for the development of masculinity. For girls and women, issues of femininity and feminine identity do not depend on the achievement of separation from the mother or on the progress of individuation. Since masculinity is defined through separation, while femininity is defined through attachment, male gender identity is threatened by intimacy while female gender identity is threatened by separation. Thus males tend to have difficulties with relationships, while females tend to have problems with individuation".[110]

Insights from Gilligan's work were used in the G.I.S.T. project. The attempt was made to modify the science curriculum by emphasising the relational aspects of science, instead of its analytical and rule-making qualities. This followed on from previous work which showed differences in science interest between boys and girls.[111] Characteristics of children and science education were dichotomised so that male and female were at the opposite end of a continuous scale:

<u>Characteristics of children and science education</u>[112]

	Boys	Girls
1.	Interested in rules	Interested in relationships
2.	Interested in machines	Interested in people
3.	Interested in fairness and justice	Pragmatic
4.	Views world as a hierarchy of relationships (competitive)	Views world as a network of relationships (co-operative)
5.	Emphasis on analytical thought	Emphasis on aesthetic appreciation
6.	Controlling of things inanimate	Nurturant of living things

As Smail[113] explained,

> "The position of school science curricula on similar scales will vary from school to school according to the interests, personalities and previous experience of the staff within the school. Our aim in the G.I.S.T. schools was to move the curriculum some way towards the right, by de-emphasising characteristics on the left of the table....and emphasising those on the right".

In this view the context in which a particular scientific fact is explained is as important as the core concept which is being taught[114], and as Smail argues,

> "if the context is concerned with people first, with machines second, if it stresses safety rather than danger, is caring and produces pleasing end products, then the girls as well as the boys will say "yes" to science".[115]

More recently Harding and Sutoris[116] have used Chodorows work, and object-relations theory to explore the differences in attitudes towards science between girls and boys and to try and understand these in terms of differences in cognitive styles between them. They argue that

> "Science and technology reflect the male characteristics of possession and control, but offer little opportunity for creative object relations involving concern or reparation. They therefore match one, particular, restricted pathway for present male development. In our society only when girls recognise in science and technology a means to make reparation, to express concern or to provide creative self-expression are they likely to commit themselves to working in these fields. This has implications for school science and technology curricula and for their expression in the world."[117]

Such developments within science education are a clear shift from what has tended to be an overriding attention on socialisation, role models and educational organisation. This work is beginning to move beyond the conceptualisation of the "girls and science problem" as simply one of access, and addresses itself to more fundamental questions on the relation between women and science which have been raised in recent years in the women's movement.

A growing body of writing from the women's movement has implicitly - and sometimes explicitly[118] - suggested that the reasons why girls do not choose science are not simply because they believe science is something boys and men do, or because discriminatory processes are in operation (although these factors are not denied), but because in some fundamental way science is masculine. As Fee argues[119]:

> "The sciences.... have been seen as masculine, not because the vast majority of scientists have historically been men, but also because the very characteristics of science are perceived as sex-linked".

The questions to be explored here are firstly in what ways is science masculine, and what does this mean? And, secondly, what implications does this have for attempts to increase the number of girls and women entering science education and scientific careers?

Male science?

In one, very obvious sense, science is understood to be masculine because of the numerical dominance of men. This is easily illustrated both for the physical and biological sciences in spite of biology being regarded as something of a girls' subject at school.[120] Such a numerical dominance of men has made it hard for women to enter into the field, to succeed in it or to feel comfortable in it. Written accounts of women's experience in the scientific world have shown that women are not only isolated and subject to both formal and informal discriminatory procedures, but that they and their work are often not taken seriously.[121] Rose notes that in the 1980s "an invisible college of feminist scientists is beginning to assemble"[122] and feminists within science have begun to fight back[123], but still men have greater numbers and are generally in the key decision-making posts.[124]

Arguably the domination of scientific fields by men has, as Keller notes,

> "led to a bias in the choice and definition of problems with which scientists have concerned themselves".[125]

Practising feminist scientists and those on the outside of science have made this claim most frequently with reference to biological and medical sciences, for example, in relation to the development of contraceptive technology[126], the technologising of childbirth[127] and more recently, to the development of reproductive technologies such as *in vitro* fertilisation and egg donation.[128] Not only are the research priorities questioned, but also the design and interpretation of experiments. Keller cites the example of research on animal learning, virtually all of which has been performed with male rats,

> "Though a simple explanation is offered - namely that female rats have a four-day cycle that complicates experiments - the criticism is hardly vitiated by the explanation. The implicit assumption is, of course, that the male rat represents the species".[129]

Taking the male experience as the norm in this way, often leads to the conclusion that the female experience, because it differs to the male, is deviant.[130]

A growing collection of work by feminist scientists is uncovering such biases[131] and comes at a time which "coincides with a conservative backlash of deterministic thinking that again tries to define 'women's place' (in the home or as subordinate worker) as a verdict spoken not by 'man' but by nature".[132] Thus feminists have been particularly critical of biological theories and medical practice which can be shown to contain within them ideological standpoints which maintain that women's inferior status is to be explained in terms of their reproductive function and therefore is natural, inevitable and essentially unchangeable. In this way the political and social questions of the distribution of social power are at one and the same time circumvented and "solved".

Such research has fueled the growing realisation in the women's movement that science cannot be ignored in spite of the fundamental disagreement there is with its present "modus operandi". Science is the most powerful legitimator of contemporary reality - in contrast to earlier times when, for example, magic or religion served this function. Scientific knowledge commands authority and confers power. The dual operations of science and technology are changing society. Faced with this the feminist case is clear - "such an important process should not be controlled exclusively by men".[133]

Ideological elements in science having been so clearly demonstrated, feminists have been led to go beyond the documentation of the male-domination of science to question whether scientific knowledge is autonomous and value-free and whether the scientific community can be conceived in terms of "universalism, communism, disinterestedness, organised scepticism".[134]

As in recent developments in the history, philosophy and sociology of science, feminists have argued that science is far from being an a-historical and a-social pursuit, divorced from political and economic considerations. The <u>result</u> of this conception of science as abstract and autonomous has been, as Overfield argues, that,

> "science is seen as a collection of pure and objective facts, almost to the extent of being a reified thing in itself. What individuals choose to do with these simple facts then, is their affair. The pursuit of scientific 'truth' is an end in itself and bears no relation

> to the society in which we live, or the circumstances or the prejudices under which this pursuit is carried out. Political questions are regarded as anathema; science is not a political form of knowledge according to this argument - and political involvement on the part of individual scientists is regarded as good enough reason to get them out. Thus, scientists are given a 'carte blanche' to persist in their role of maintaining the status quo under the guise of (and with all the glory of) objectivity. As a result, individual scientists are both absolved from blame should their scientific discoveries be 'perverted' or misused, and are prevented from seeing science as a political force, and its practitioners as having some responsibility in how it is used".[135]

Contrasting this idealistic conception of science with both the reality of scientific practice and the reality of some of the worst effects science has had on the world, many feminists writing on science have concluded with Rose that "science and technology must be transformed for the alternative to doing so is nuclear exterminism".[136] Thus, within the feminist critique of science there is both a sense of the need for an alternative science to emerge and a conception of what that alternative might involve.

i) Objectivity as male ideology.

At its most radical, the argument not only challenges the autonomy of science, but questions the very possibility of an objective understanding of the world. A central proposition is that what has been termed "scientific objectivity" has simply been "male rules and categories of understanding".[137] Overfield argues that,

> "the scientific ethic is the male ethic; it is the ethic of dominance and control; it is the ethic which encodes a dichotomous and unequal division of the objects and events of the world into man/woman, norm/deviant, dominant/subordinate, rational/emotional".[138]

What is being argued here is that the "form of knowing" represented by the natural sciences is a way of conceptualising the world with reference to men's own experience of it. Support for such views come from histories of science which locate the "founding fathers" of Western thought in their sexual-political context.[139] The argument here is that men, as the socially powerful sex, were able to define reality in terms of their own experience. Aristotle, for example, defined female as "mutilated male" and this basic definition informed not only his and others biological thinking, but also fundamental orientations in philosophical and religious thought.[140] Now, as then, maleness is active, femaleness is passive, maleness is spiritual, femaleness is material, male is associated with mind and reason, female with body and unreason.

From this some feminist thought has taken the objective/subjective distinction in science as representing another manifestation of Aristotelian dualism and have concluded that what is called scientific objectivity is simply a form of male ideology. Two consequences, it is argued, spring from this. The first is that in order to enter the realm of abstract (scientific) thought and to leave emotion behind, women must forgo what they believe, or have always been led to believe, is their nature.[141] Thus is the "girls and science" problem not simply that of the discriminatory processes which deny girls education and opportunity, but rather the result of "the incongruity or lack of fit between 'science' and 'the female mind' ".[142] The second is that as modern science has only developed from half of human experience - male experience - what women could bring to science, that is, experiences of self and nature different to men, have been and continue to be regarded as deviant. Thus Wallsgrove speaks for this view when she argues;

> "it's time to force our culture to re-examine and re-value women's traditional 'sentimentality', women's feminine belief that the quality of life has priority over economics, or efficiency or 'rational' planning".[143]

Women are seen as the bearers of a new science because their values are regarded as antithetical to the present quest for power and domination of nature embodied in the current scientific enterprise. An alternative science, it is argued,

> "should embody the ideas of co-operation and the sharing of knowledge, both within the scientific community and with non-scientists. It should be concerned with the benefit of the community and the balance of nature. Women could play a large part in creating a truly human science".[144]

This critique documents women's very real dissatisfactions with, and antagonisms towards, a form of knowledge which is perceived to be a threatening force and over which they can have little control.[145] However as a critique it presents several problems, both for the better understanding of the operation and practices of modern science and for women's cause.

Firstly the critique argues against the sharp dichotomous conception of the world into objective/subjective; man/woman; masculine/feminine and rightly questions this as an accurate portrayal of science, or indeed of women and men.[146] However, in speculating upon an alternative science this dichotomy is built upon. Femininity must replace masculinity in science; women's values must replace men's. The goal is of a "woman-centred science" which "would be so radically different that it would no longer be invested with the meaning of 'science' as we understand it".[147] The viewpoint raises two specific problems, one of biological essentialism and the other of relativism.

Little discussion is offered of the reasons why the values of men and women might be different. Wallsgrove calls upon the notion of socialisation and suggests that this is the means by which men retain power over women, for in a patriarchal society masculinity is accorded more power and status than femininity.[148] However, in her call for a re-evaluation of women's values, it is implied that these are not the product of a social process, but inherent. An alternative social order (and science) is sought in which women and feminine qualities are regarded as superior to men and masculine qualities. The danger here is that women define themselves in exactly the way that has been used to justify their subordination[149] and a vision of the "separate but equal" philosophy of the nineteenth century is evident in which women, proclaimed as a civilising force, were denied access to most areas of public life.[150]

The second problem is that of relativism. If scientific objectivity is seen simply as masculine ideology then "the claim of science to be the arbiter of truth must be accepted or rejected wholesale".[151] If rejected, then what is left is "complete cultural relativism where no one form of the production of knowledge could claim truth status over any other".[152] This would not simply be an epistemological problem, but a political one, for, in the absence of any criteria of validity which had been mutually agreed it would only be the most powerful social groups who could successfully defend their interpretation of truth.[153] In the dismissal of objectivity as male ideology the danger here is also that women turn away from science, celebrating female subjectivity, "leaving rationality and objectivity in the male domain, dismissed as products of a purely male consciousness".[154] In short, this position can easily lead to one of anti-science.

These problems arise because nowhere is there any clear discussion of what is meant by science. Overfield admits that the term "science" is used rather loosely in her work "in regard to both the 'pure' and 'applied' sciences, reasoning that the same scientific ethic is common to all".[155] Wallsgrove defines science as that "which consists of breaking things down (analysis) and labelling them (classification) combined with logic".[156] What needs unravelling here is how far the critique is actually directed against all disciplines and forms of knowledge which come under the term "science", or rather the contemporary ideology of science which maintains that it is an autonomous pursuit, abstracted from any social or political concerns and value-free, or even against a particular scientific method which claims objectivity for statements which, only in fact represent a partial viewpoint.

What I would argue is that some feminist criticism of science has taken all the claims of science to be a value-neutral, objective pursuit, in order to reject them. "Science" in fact covers a wide range of knowledge areas. There are the social sciences (in which women are well represented) and the natural sciences. Since the 1840s, however, the natural sciences have increasingly taken the term "science" for themselves. This has led to a confusion between scientific method - which can be found in operation in both the social and natural sciences - and the usage of, or the products of natural science.[157] Furthermore, confusion also exists between empiricism and science. That is, the empiricist method, the concern with "empirical generalisations or causal connections of observational terms through the observation of empirical association",[158] - is taken to represent the scientific method per se. Willer and Willer argue strongly that empiricism is a conservative and reactionary form of science based as it is on observations of what is and what was.[159] Empiricism is thus context and value bound. What empiricist ideology claims however is that these observations are value neutral and thus objective.

It is clear that it is forms of empiricism within the biological and medical sciences which led to "scientific" conclusions regarding women and their subordinate position in society - conclusions which feminists have rightly contested. However, contesting such theories does not necessarily lead to the rejection of the whole scientific enterprise.

By contrast, it can be argued that there can be some mutually agreed criteria for comprehending the natural and social world. The Willers defend science on the grounds that it "assumes no empirical truths and thus is not restricted by them".[160] It is concerned with rational connection - the connection of non-observable concepts, empirical meaning is gained "through the abstractive connection of theoretical concepts with observations".[161] In this way science is a distinct form of knowledge from every day knowledge which is based on observation and habit.

This is not to deny that science, in this way, is free from values. Scientific method cannot operate without the intrusion of values. However, there is a difference between an ideological form of science - empiricism - which is context bound, and a context-related science. Studies in the sociology of science have clearly shown how the presuppositions and assumptions of scientists enter into the research process, from the construction of the hypotheses, through the selection of facts to the final conclusions.[162] But, there is a strong case for arguing that science is a "distinct and relatively autonomous cognitive social practice".[163] As Rose and Rose argue, the non-neutrality of science lies not in the "individual 'facts' accumulated by science", but, "in the selection of facts to accumulate, experiments to perform and theoretical frameworks within which to set these facts".[164]

In conclusion to this section it should be stated that whilst the above critique documents women's very real dissatisfaction with and antagonism towards a form of knowledge which is perceived to be a threatening force it does not actually take us much further as a means of elucidating the dynamics of science and how women are excluded from it. As a critique it is anti-science because of its implication that all things labelled as science are necessarily oppressive to women and thus must be changed.

ii) <u>"Objectivist ideology"</u>

From a different perspective, other feminist writing has challenged contemporary scientific practice as oppressive towards women, but has done so in a way which attempts to identify what is ideological in science, and yet to retain what is legitimate, valid and useful.

As Fee notes, a feminist analysis of science and objectivity needs to be developed

> "in ways which will allow us to identify those aspects of scientific activity and ideology which need to be questioned and rejected, without at the same time abandoning the ideal that we can come to an ever more complete understanding of the natural world through a collective and disciplined process of investigation and discovery".[165]

This is similar to Keller's perception of "the task of a feminist theoretic in science", as being

> "to distinguish that which is parochial from that which is universal in the scientific impulse, reclaiming for women what has historically been denied to them; and to legitimate those elements of scientific culture which have been denied precisely because they are defined as female".[166]

The central assumption here is that there is no necessary, inherent conflict between feminism and science and where conflict may exist between women's values and the values of science, this may "carry a liberating potential for science".[167]

Thus Keller argues that a distinction must be made between the "objective effort" - understood as the attempt to understand the world in rational terms - and the "objectivist illusion", by which is meant that the assumptions, prejudices and experiences of the individual are ignored in the scientific process such that one comes to regard "one's own perspective as immediately objective and absolute".[168] What needs to enter the scientific process along with rational and empirical enquiry is "the additional process of critical self-reflection".[169] In this way objectivity can be reconceptualised as a dialectical process - moving towards a unity of thought and feeling, rather than a separation of them.[170]

For feminists, Keller suggests that "the ideological ingredients of particular concern are found...where objectivity is linked with autonomy and masculinity, and in turn the goals of science with power and domination".[171]

The radical science movement since the 1960s has paid considerable attention to the supposed social and political autonomy of science. It has shown how science is intimately related to society in that particular social formations have determined the type of scientific knowledge produced and how this in turn has reinforced and has served particular political and economic interests within it.[172] Fee gives the example of Greek "scientia" in which

> "the production of natural knowledge was divorced from the practical problems of technological production, because in a slave society the citizen philosopher had no need to be concerned with manual labour, and the slave had no social possibility for producing formally articulated knowledge".[173]

Thus, it would seem that in a social formation in which men have greater power than women and in which men need not be concerned with women's problems except insofar as there are possibilities for domination and control,[174] it cannot be expected that science, in its selection of facts, theoretical frameworks and so on, will be woman-orientated. In short, as Fee notes, "we can expect a sexist society to develop a sexist science".[175]

Alternatively, in Fee's view, a feminist science

> "would not be based on the divorce between subjectivity and objectivity but would rather seek to integrate all aspects of human experience into our understanding of the natural world".[176]

Whilst it is not possible to conceive in advance what a "feminist science" would be like,[177] moves towards such a science might begin, as Fee suggests, by accepting science as "an historically determined human activity and not as an abstract, autonomous force".[178] Furthermore, "allowing the collective definition of the problems and the methodology of research",[179] the selection of problems to be investigated, theories to be used, experiments to be performed, would not be chosen by one interest group as against another. An example Fee gives here is of the recent history of occupational health research in Italian factories. This changed from an activity by specialists commissioned to investigate a potential problem, to one involving collectively produced information by the workers.[180]

Fee's approach maintains a commitment to the possibility of scientific knowledge whilst being sensitive to the social and ideological elements within it. The "maleness" of science is conceived in cultural terms. That is, men have had and continue to have greater social power than women so they have been in a better position to define the problems and methodology of science. Work such as this is important in both adding the question of gender to the critiques of science developed by the radical science movement in the '60s and '70s and by showing the processes involved in the production of scientific knowledge. In terms of the question of women and science and the scientific education of girls, it shows that simply encouraging more girls to study science to enter the professions will bring few changes. The approach in this work also enables analysis of the effects women's absence from science has had - effects which feminist historians of science are beginning to discover.[181]

A shortfall of this work however is the lack of any clear explanation of the relation between masculinity and science other than by invoking the congruence between the object/subject and masculine/feminine dichotomies. This has all the dangers noted above of defining women in ways that have been used as justifications for women's exclusion from science.[182]

In contrast, it is precisely this relation between masculinity and objectivity which is the focus of much of Keller's writing on feminism and science.

Keller calls on psychoanalytic theory, particularly the branch known as object-relations theory, to support her argument firstly, that "the impulse towards domination does find expression in the goals (and even in the theories and practice) of modern science"[183] and secondly, that this can be understood as a projection of a specifically male consciousness.[184] Where Keller's analysis importantly differs from the preceding analyses is that she recognises that this impulse towards domination is but one aspect of the scientific tradition.[185] She argues that the scientific process is a dialectical one - one pole of the dialectic being a conception of science as "dominating" and, the other as "conversing" with nature. Importantly these differences between dominating and conversing are not the prerogative of one sex or the other, or of one epoch or another, but rather "can be seen as representing a dual theme played out in the work of all scientists, in all ages".[186] But what has happened in the history of science is that one pole - the dominating - has had greater weight. Thus the task is "to attend to the evolutionary process that selects one theme as dominant".[187]

Here Keller argues that a particular selection process has operated within science which has had consequences both for the type of people entering science and the methodologies, aims and theories preferred. Because science has been identified as masculine, those who have regarded themselves as masculine (mostly men) - characterised in psycho-analytic terms by those seeking autonomy and separateness - have chosen science.[188] This has in turn influenced the type of methodologies, theories and aims selected, which has in turn perpetuated the characterisation of science as masculine.[189] As Keller explains, "individuals drawn by a particular ideology will tend to select themes consistent with that ideology".[190] An alternative selection process would it seems depend on the characterisation of science as being able to gratify other (i.e. non-dominating) emotional needs.

Importantly however she notes that "stereotypes are not binding....they do not describe all or perhaps any individuals",[191] and in this way there is an "ongoing contest within science" - a contest between, for example, two or more theoretical models.[192] Understanding science in this way, she argues

> "that we need not rely on our imagination for a vision of what a different science - a science less restrained by the impulse to dominate - might be like. Rather, we need only look to the thematic pluralism in the history of our own science as it has evolved".[193]

The task then for feminists is, she argues,

> "a historical one, but finally a transformative one. In the historical effort, feminists can bring a whole new range of sensitivities, leading to an equally new consciousness of the potentialities lying latent in the scientific project".[194]

Keller then offers valuable insights into the processes by which the ideology of scientific objectivity has come to be associated with masculinity and where the possibilities for an alternative version of science can lie.

Women in Keller's view are in a position to realise this alternative not because of any essential biological capacities, but rather for several reasons related to the structure and organisation of society. The source of the division between women and men is both biological and cultural: biological because women bear children and men do not, cultural because different qualities are assigned to masculinity and femininity. In a male dominated society masculinity has been a means of power over subordinate groups. "Masculine" qualities tend to have higher status than "feminine" ones. Boys have to learn to be masculine[195] just as girls have to learn to be feminine. Feelings of aggression or anger, for example, are actively discouraged in girls as are tears in boys. Furthermore, because women have internalised their status and also because they are positioned differently in the social order to men, it is possible, as Spender argues, "to speak of women and men as inhabiting different worlds which give rise to sexually differentiated meanings and explanations of these worlds".[196] This different position which women have in the social order, which does derive in part from the biological fact that women bear children, means that women are "more situationally defined than men, <u>deriving</u> their identity from their environment rather than distinguishing themselves from it".[197] Thus, as Keller notes:

> "if women are in a privileged position to bring the epistemological critique necessary for that liberation,

it is both because we have been especially vulnerable - viewed as passive, natural objects - to the logic of domination, and because our status as inhabitants of a different (female) culture provides us with an invaluable perspective - the view from the periphery".[198]

It is made clear, however, that for any transformation of science to occur and be successful, the social context in which scientific work is done must also change. Consciousness cannot change without change in the economic and social structures which, in some way determines that consciousness.[199] Lowe makes this point with clarity:

"As long as there are no major changes in women's role in the society at large, women will remain relatively powerless minorities in male professions. Furthermore, the goals of science are often in large part determined by forces outside science, such as corporations and government, through control of resources. As long as this remains true, there may be little possibility of changing the nature of the competition for those resources, even if women in science are able to agree on an alternative model for doing science, and work together to attain that goal".[200]

Science then is not male, nor is it inherently masculine. Rather a masculinist scientific ideology has been dominant in the sciences. Masculine characteristics have been selected out in favour of feminine - although science has always contained both within it - and this process of selection has ensured that those who most identify themselves as masculine (mostly men) have become scientists. This gender ideology in science has in turn reinforced and been reinforced by the economic, political and social context in which science has developed.[201] A change in the former requires a change in the latter.

The value of this feminist critique lies in enabling a conceptualisation of the "girls and science" problem which looks to the processes operating within science and society which have had negative consequences for girls achievement in science. It is to an investigation of these processes in that microcosm of scientific activity known as school science that the following chapters are devoted.

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7. Quoted in Ministry of Education, Technical Education, Cmnd. 9703, HMSO 1956, p.4.
8. Unveiled at the Labour Party conference, Scarborough 1963. For discussion of this, see "The white hot technological revolution - five years after", New Scientist, 26 September 1968, p.644 et passim.
9. When the present Conservative government was elected into office in 1979 and began to increase cuts in public expenditure, science was one of the few areas not subject to spending cuts. A government White Paper in 1980 pledged its support to basic science in the U.K. "as an investment in the country's industrial and intellectual future". New Scientist, 3 April, 1980, p.4.
10. Ministry of Education, 1956, op.cit.

11. This description is remarkable for the constancy of its use over the last thirty-five years, for example: "an untapped pool", Sir Hugh Linstead, T.E.S., 7 October 1955; "great reserves of scientific and engineering talent which go undeveloped", New Scientist, 13 December 1956; "a largely neglected source of recruitment", The Guardian, 15 July 1957; "a great reserve of ability as yet comparatively untapped", T.E.S., 25 September 1969; "an important reserve of untapped ability", Robbins Report, Appendix I, p.82, 1963; "a great deal of human resources is not being channeled 'the right way'", Physics Education, Vol.16, 1981; "talents and abilities that girls have to offer cannot be neglected", T.E.S., 8 May 1981; "women have a hell of a contribution to make", Sir Michael Edwards, T.E.S., 10 July 1981; "it is certainly not in the best interests of the country, nor of the girls themselves, that potential skill and talent of this calibre should be wasted", Baroness Lockwood, T.E.S., 12 March 1982.
12. reported in E.O.C. News (Journal of the Equal Opportunities Commission) Feb./Mar. 1981, p.7.
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17. This point is made by Rossi, A., (Women in Science - Why so Few?, Science, Vol.148, 1965, p.1196) when she notes that the campaign to get women to "enter more fully into the occupational life of the (U.S.A.)" reflects the existing sexual division of labour, such that "a steady supply of older married women secretaries, clerks, machine tenders and technicians seems assured".
    See for example:
    Ministry of Education, 1956, op.cit., p.31.
18. See for example: British Federation of University Women, Opportunities for Girls and Women in Science and Technology, B.F.U.W., 2nd edn., 1961, p.31.
19. See for example: T.E.S., 18 Dec. 1959, p.757. Speaking in a Lords debate, Lord James of Rusholme said:

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Dialogue, 1968, p.3). It too established various curriculum initiatives in science: 1965 - The Secondary Science Project (in collaboration with Nuffield); 1967 - Project Technology; 1967 - Science 15/13.

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49. Kelly, 1978, op.cit., p.3.
50. ibid.
51. Adamson shows that within the biological sciences there has been a decline in the proportion of women employed. This trend is evident in Australia, Britain, Canada and the United States. She gives the following table:

Percentage of university lecturing staff in the biological sciences who are women:

	1950	1975
Australia	17	8
Britain	14	7
Canada	12	8.6

Adamson, H., Changing pattern of employment of women in the biological sciences, Paper given to the Australia and New Zealand Association for the Advancement of Science, 1977.
52. Kelly, A. "Science for men only?", New Scientist, 29 August 1974, pp.538-540.
53. See here Ministry of Education, 1956, op.cit., and for a discussion of the policy implication of these assumptions see Wolpe, A.M., "The Official Ideology of Education for Girls", in Flude, M., and Ahier, J.,

(eds), Education, Schools and Ideology, Croom Helm, 1974, pp.138-159.

54. See Brown, op.cit. Arregor, C., "Why so few women scientists and technologists?", New Scientist, 3 Jan. 1957, pp.14-17; Alston, H.G., "Technological training and employment of women", The Woman Engineer, Vol.VIII, no.4, Spring 1957, pp.13-17.

55. Arregor, C., op.cit., p.14.

56. ibid.

57. ibid.

58. Coote, A., and Gill, T., Women's Rights: a practical guide, Harmondsworth, Penguin Books, 2nd ed., 1977.

59. This is not to say that interest in girls' science education was immediately a priority, or even of importance to many. It is only now - in the mid '80s - that the problem is widely recognised.

60. D.E.S., Curricular Differences for Boys and Girls, Education Survey no.21, H.M.S.O., 1975.

61. ibid. Table 7, p.13:

Pupils being offered, choosing and taking particular subjects.
(Corrected percentages for comparing segregated and mixed schools)
(Figures relating to science only given here)

		Being offered. Single Sex	Mixed	Choosing. Single Sex	Mixed	Taking. Single Sex	Mixed
		% of totals.		% of those offered.		% of totals.	
Physics	Boys	85	91	60	52	51	47
	Girls	62	75	23	15	14	11
Chemistry	Boys	81	79	36	35	29	28
	Girls	75	78	27	22	20	17
Biology	Boys	79	91	39	30	31	27
	Girls	96	96	49	53	47	51

62. Harding, J., "Sex differences in science examinations", in Kelly, (ed.), 1981, op.cit. pp.192-204.

63. ibid., p.203.

64. Centre for Science Education, Chelsea College, Girls and Science Education - Cause for Concern, Chelsea College, 1975.

65. Harding, J., "What Action should we take?", in ibid., p.75.

66. ibid., p.76.

67. ibid.

68. ibid., p.77.

69. ibid.
70. ibid.
71. ibid.
72. ibid., pp.77-79.
73. ibid., p.78. The conference expressed the hope that "Girls and Science" should provide the focus for discussion at a future Annual meeting. The A.S.E. established a Girls and Physical Science Sub-Committee in 1979, chaired by Dr. Jan Harding. In 1980 the Committee was "in active discussion with the Department of Industry over the mass production of a tape/slide sequence for use with classes in preparation for option choices". After the 1981 Annual Meeting the Sub-Committee established "a number of curriculum working groups throughout the country with the task of producing physical science modules for use in year III, when the majority of pupils make their option choices". See Education in Science - Bulletin of the A.S.E., no. 85, November 1979, p.16; no. 90, November 1980, p.16; no. 95, November 1981, p.22. After 1981 there is no evidence of further activity by this committee or of the physical science modules discussed.
74. Private discussion with Dr. Jan Harding.
75. Harding, J., "Sex Differences in examination performance at 16+", Physics Education, Vol.14, 1979, pp.280-284, and Harding, J., "Sex Differences in Science Examinations", in Kelly, (ed.), 1981, op.cit., pp.192-204.
76. Kelly, A., "Girls and science education - is there a problem?", in Kelly, (ed.), 1981, op.cit., p.1.
77. Kelly, A., "Retrieving the Missing Half", in Kelly, (ed.), 1981, op.cit., pp.288-9.
78. ibid, p.277; Kelly, A., "Women in physics and physics education", in Lewis, J.L. (ed.), New Trends in Physics Teaching, Vol.III, Unesco, 1976, pp.241-266.
    Samuels, J., "Feminism and science teaching, some classroom observations", in Kelly, (ed.), 1981, op.cit., pp.247-256 (p.248).
79. Kelly, 1976, op.cit. p.250; Walford, G., "Sex bias in physics textbooks", S.S.R. Vol.62, no.219, Dec. 1980, pp.220-227.
80. Harding, 1979, 1981, op.cit.
81. Blackstone, T., and Weinrich-Haste, H. "Why are there so few women scientists and engineers?", New Society, 21 February, 1980, pp.383-4.
82. Harding, op.cit., 1981; Weinrich-Haste, H. "The image of science", in Kelly, (ed.), 1981, op.cit., pp.216-231; Ebbut, D., "Science options

in a girls' grammar school", in Kelly, (ed.), 1981, op.cit., pp.113-122.

83. Newton, P., "Who says girls can't be engineers?", in Kelly, (ed.), 1981, op.cit., pp.139-149; Whyte, J., "Sex-typing in schools", in Kelly, (ed.), 1981, op.cit., pp.264-274.

84. Newton, op.cit.

85. Smithers, A., and Collings, J., "Girls studying science in the sixth form", in Kelly, (ed.), 1981, op.cit., pp.164-179; Ebbut, 1981, op.cit. However, more recent work by Smithers and Collings suggest that for "both sexes intelligence and low person orientation are the most important factors in science choice and for girls, gender identity and perceived maleness of subjects and co-education.....appear to make relatively little contribution". The Guardian, January 11, 1983.

86. Hills, P., and Shallis, M., "Images of Science", New Society, 28 August, 1979, pp.477-478.

87. See for example, Sharpe, S., Just like a girl - How girls learn to be women, Penguin, 1976.

88. Ormerod, M.B., "Factors differentially affecting the science subject preferences, choices and attitudes of girls and boys", in Kelly, (ed.), 1981, op.cit., pp.100-112.

89. See note 36.

90. E.O.C. News, June/July 1980; Hearn, H., "Girls for Physical Science", Education in Science, April, 1979, pp.14-16. At Kidbrooke School in South London, teacher discussions, smaller classes, the deployment of women teachers as much as possible and intensive counselling and careers advice at option time, were tried, (T.E.S. 24 June, 1983). At Tameside, Greater Manchester, two teachers were appointed "to encourage interest and enthusiasm for the sciences amongst girls", (Observer, 1 February 1981, p.16; see also Contributions to the second GASAT Conference, op.cit., pp.234-5.

91. See here for example, Kelly, 1976, op.cit., pp.252-254. See also, Smail, B., "Getting science right for girls", Contributions to the second GASAT Conference, op.cit., pp.163-174.

92. HMI Series for Discussion, Girls and Science, HMSO, 1980, p.2.

93. Dr. Jan Harding - private discussion.

94. Deem, R., Women and Schooling, R.K.P. 1978, pp.76-78.

95. D.E.S., Aspects of Secondary Education in England, HMSO, 1979, pp.164-178.

96. As Harding notes, "Whilst the Review is concerned with the science education of pupils of all abilities, specific attention is being given to

the particular aspirations of girls". Harding, J., Switched Off: The Science Education of Girls, Schools Council Programme 3, Developing the curriculum for a changing world. Longman for Schools Council, 1983, p.48.

97. There is perhaps some room for optimism here, but in some science-related fields such as computing, while some enthusiastic staff members may be running "girls-only" computing clubs, there is no evidence of policy on this. I am indebted to Jane Walters for this point.
98. Simonis, D.A., "Girls' science: Designing a sane new world", Contributions to the second GASAT Conference, 1983, op.cit., pp.71-78.
99. For a fuller discussion of this in the development of girls' science education see chapter five.
100. Clearly there is a problem of evaluation of strategies here as well. A negative evaluation of a large project received headline news in an educational paper, yet this evaluation was not all negative. Such reporting can obviously do much damage. See Wilce, H., "No role change for science girls", T.E.S., 2 March 1984, p.1.
101. Kelly, A., "Report on the opening and summing-up sessions", Lie, S., (ed.), Girls and Science and Technology - The 2nd International GASAT Conference, Conference Report, Institute of Physics, University of Oslo, 1983, pp.51-57 (p.52).
102. ibid., p.55.
103. ibid.
104. ibid., p.54.
105. Chodorow, N., The Reproduction of Mothering - Psychoanalysis and the Sociology of Gender, University of California Press, 1978.
106. Gilligan, C., In a different voice - Psychological theory and women's development, Harvard University Press, 1982.
107. See here for example the work by John Head: "Personality and the Pursuit of Science", Studies in Science Education, Vol.6, pp.23-44, 1979; "A model to link Personality Characteristics to a Preference for Science", European Journal of Science Education, Vol.2, pp.295-300, 1980; "Sex Differences in Adolescent Personality Development and the Implications for Science Education", Contributions to the second GASAT Conference, op.cit., pp.53-61.
108. Chodorow, op.cit., p.47.
109. ibid, p.127.
110. Gilligan, op.cit., p.8.

111. Smail, B., "Getting science right for girls", Contributions to the second GASAT Conference, op.cit., pp.163-174 (pp.167-168).
112. ibid., p.169.
113. ibid.
114. ibid. This is a view supported by the findings of Johnson et al., in their paper, "The science performances of boys and girls aged 11-15", Contributions to the second GASAT Conference, op.cit., pp.93-106.
115. Smail, op.cit., p.173.
116. Harding, J., and Sutoris, M., "An Object Relations Account of the Differential Involvement of Boys and Girls in Science and Technology", Paper presented at the 12th IPN Symposium, Interests in Science and Technology Education, Kiel, April 2-6, 1984.
117. ibid.
118. See here, for example, Curran, L., "Science Education - Did She Drop Out or Was She Pushed?", in Brighton Women and Science Collective, (eds.), Alice Through the Microscope - The Power of Science Over Women's Lives, Virago, Brighton 1980, pp.22-62.
119. Fee, E., "Is Feminism a threat to scientific objectivity?", International Journal of Women's Studies, Vol.4, no.4, Sept./Oct., 1981, pp.378-392 (p.281).
120. For documentation of the numbers of men in science compared to women, see for example:
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121. See here for example:
Chapelinsky, A.B., et al., "Women in Chemistry", in Arditti, R., Brennan, P., and Cavrak, S., (eds.), Science and Liberation, South End Press, Boston, Massachusetts, 1980. Grote, J., "Why a woman left science", New Scientist, Jan. 26, 1978, pp.222-3; Sayre, A., Rosalind Franklin and D.N.A., W.W. Norton & Co., New York, 1975. Rossiter, M., "Fair Enough?", Isis, Vol.72, no.261, March 1981, pp.99-103. Weisstein, N., "Adventures of a Woman in Science", in Hubbard, R., Henifin, M.S., & Fried, B. (eds.), Women Look at Biology Looking at Women, Shenkman Publishing Co., New York, 1979, pp.187-201.

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128. Arditti, R., Duelli-Klein, R., and Minden, S. Test-Tube Women, Pandora Press, 1984.
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143. Wallsgrove, R. "The Masculine Face of Science", in Brighton Women and Science Group (eds.), op.cit., pp.228-240 (pp.233-234).
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146. Overfield, op.cit., p.217.
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148. Wallsgrove, op.cit., p.231.
149. Keller, 1982, op.cit., p.156.
150. For essays on this see, Vicinus, M. (ed.), Suffer and be still : Women in the Victorian Age, Indiana University Press, 1980.
151. Fee, op.cit., p.383.
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154. Keller, 1982, op.cit., p.117, see also Fee, op.cit., p.384.
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158. Willer, D. and Willer, J., Systematic Empiricism - A Critique of Pseudoscience, Prentice-Hall Inc., New Jersey, 1973, p.20.
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165. Fee, op.cit., p.384.
166. Keller, 1982, op.cit., pp.117-8.
167. ibid., p.113.
168. ibid., p.118.
169. ibid.
170. ibid.
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174. Evident in medicine for example. See Ehrenreich, B., and English, D., For her own good - 150 years of the Experts Advice to Women, Pluto Press, 1979. And, as Rose, 1982 op.cit., p.353, notes, "excluded from science women....can only protest and seek to mobilise humanistic men to develop an alternative".
175. Fee, op.cit., p.388.
176. Fee, op.cit., p.389; see also, Rose, 1982, op.cit., p.368.
177. Fee, op.cit., pp.388-89.
178. Fee, op.cit., p.380.
179. Fee, op.cit., p.390.
180. ibid., similarly Rose cites in this context the Lucas Aerospace workers Alternative Plan. Rose, 1982, op.cit., p.360.
181. See for example, Trescott, M.M., (ed.). Dynamos and Virgins Revisited - Women and Technological Change in History, Scarecrow Press Inc., London, 1979, for discussions of directions of technology under women's hands.
182. See Keller, E.F. "Women and Science - Two cultures or one?", in International Journal of Women's Studies, op.cit., pp.414-419.
183. Keller, 1982, op.cit., p.132.
184. For a discussion of her work on object relations theory see, Keller, E.F., Gender and Science, Psychoanalysis and Contemporary Thought, Vol.1, 1978, pp.409-33.
185. "Francis Bacon provides us with one model, there are many others. For an especially striking contrast, consider a contemporary scientist who insists on the importance of 'letting the material speak to you', of allowing it to 'tell you what to do next' - one who chastises other scientists for attempting to 'impose an answer on what they see'. For this scientist, discovery is facilitated by becoming 'part of the system', rather than remaining outside; one must have a 'feeling for the organism'". Keller, 1982, op.cit., p.123.

186. ibid., p.124.
187. ibid.
188. See here, for example, Hills and Shallis, op.cit., and Dixon, B., "Your typical scientist", New Society, 14, October 1982, pp.74-6.
189. Keller, 1978, op.cit., p.427-8.
190. Keller, 1982, op.cit., p.124.
191. ibid., p.124.
192. ibid.
193. ibid., p.125. Indeed, other historians of science have argued that there is a subjective side to science and that written accounts of science exclude mention of "imaginative leaps", "intuition", etc. See: Mitroff, I.I. The Subjective Side of Science : a philosophical inquiry into the psychology of the Apollo moon scientists, Elsevier, Amsterdam, 1974; and, Gilbert, G.N., and Mulkay, M., "Participants' Histories and the Historian's Histories of Science", ISIS, Vol.75, no.276, pp.105-125.
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2. The participation of women in the scientific culture 1780 - 1850. Some implications for later developments in girls' science education.

This chapter seeks to investigate the period in science immediately before its emergence as a specialist pursuit and immediately before the study of science became established in schools and other educational institutions. It is believed that an understanding of the developments within the structure of science and of society during the period 1780 - 1850 in relation to women's position in society and their participation in science will illuminate some of the later developments in science education for girls.

The Industrial Revolution and the emergence of a scientific culture.

Between the years 1780 - 1850 the "dual revolution" - the French revolution of 1789 and the British Industrial Revolution - had profound and lasting effects upon the structure and culture of British society[1]. The Industrial Revolution was a revolution in economic and technological developments. As Landes documents,

> "in the 18th century a series of inventions transformed the manufacture of cotton in England and gave rise to a new mode of production - the factory system...The abundance and variety of these innovations...may be subsumed under three principles: the substitution of machines...for human skill and effort; the substitution of inanimate for animate sources of power, in particular the introduction of engines for converting heat into work, thereby opening to man a new and almost unlimited supply of energy; the use of new and far more abundant raw materials, in particular the substitution of mineral for vegetable or animal substances"[2].

Such changes brought with them a transformation of the social order and a transformation in the balance of political power. The introduction of new ways of working the land and the growth of the factory system attracted people to the new industrial centres. With the urbanisation of Britain came rapid population growth. Manchester's population for example increased from around fifteen thousand in 1760 to a quarter of a million in 1831[3]. In the industrial centres of the country a factory proletariat grew and an industrial bourgeoisie emerged, eclipsing the power of the landowning aristocracy[4].

Relations between men and women also changed. For centuries prior to the Industrial Revolution women were engaged in productive work, which under the handicraft and domestic systems was for the most part home based[5]. As Pinchbeck notes,

> "For much of their work prior to the Industrial Revolution women themselves received no wages. Among the industrial classes the earnings of wives and children were often included in the sum paid to the head of the family, and among agriculturists and traders marriage was most often a business partnership in which husband and wife worked together in their joint interests. But wherever women were unable to assist in their husbands work it was necessary for them as a rule to become wage earners themselves. Public opinion in the eighteenth century expected women and children to earn at least sufficient for their own maintenance and men's wages were based on the assumption that they did so".[6]

One major consequence of the Industrial Revolution was that the home was no longer the centre of production. Manufacture was instead concentrated in the mills and factories which could accommodate the new industrial machinery[7]. Women of the "industrial classes" were thus "compelled to follow their work and become wage earners in the outside world"[8], but for the emergent middle classes the separation of work from home had, as Hall argues,

> "important effects on the organisation of work within the family and the marking out of male and female spheres. Men were increasingly associated with business and public activities which were physically and socially separated from the home; women with the home and children".[9]

Underpinning this separation of male and female spheres was the development of the bourgeois "domestic ideology" which,

> "was premissed on the notion of a male head of household who supported his dependent wife and children. The women and children were able to be sheltered from the anxieties of the competitive world by living in their 'haven' or 'home'".[10]

That women and children of the "better classes" were deemed to require such protection is a comment upon the nature of society around the turn of the eighteenth and nineteenth centuries. The rapid growth of large industrial towns and cities had brought with it particular social perils. As Thackray notes for Manchester there were,

> "food riots in 1757, 1762, 1795, and 1812; political riots in 1792, 1809, 1812 and 1819, culminating in the tragedy of Peterloo. The accepted norms also included endemic drunkenness, gambling, cockfighting

> and prostitution...At least until the end of the hungry forties it was a violent culture in which the illiterate mob perpetually menaced the fragile social veneer maintained by the higher orders of the explosively growing town".[11]

Persistent concerns of the time - and throughout the nineteenth century - were working class crime, irreligion, immorality, improvidence and drunkenness. There was a sense that social stability was threatened not only by industrialisation and urbanisation, but also by reform agitation and Jacobinism inspired by the French Revolution[12], and later the end of the Napoleonic Wars in 1815 and the resultant demobilisation and economic slump[13].

The dissenting religions, particularly the Evangelicals, Quakers and the Unitarians played a strong role in inspiring a "revolution in manners and morals" in response to these threats to social stability. Taylor argues that large sections of the English upper and middle classes shaken by revolutionary fervour in France turned to the revivalist church for a "spiritual re-ordering of society". Jacobinism was conceived as "'moral malady' which could only be cured by a stiff dose of 'vital religion' - a 'practical Christianity' in which godliness, cleanliving and patriotism were inescapably joined".[14]

For women it was this revolution which had profound and lasting effects promoting as it did specific notions of femininity based on the location of women within the private sphere of the family. As Purvis argues,

> "...the establishment of the domestic ideology within the dominant bourgeois culture was such that the social construction of the female gender came to be identified, in society at large, with domesticity...this was something that both middle class and working class women through the category of their common sex had in common. But...within the broad identification of femininity with domesticity...the bourgeoisie upheld ideals of femininity that were class specific".[15]

For middle class women the ideal of femininity was that of the "perfect wife and mother", requiring a woman to "provide a well-organised, stable, supportive environment for her husband and children"[16]. In doing so she was expected to "display certain Christian virtues such as self-denial, patience, resignation and silent suffering"[17]. Above all, she was expected to be "ladylike". This involved managing a household but not undertaking the routine manual work; engaging in unpaid philanthropic work, but never waged labour and wearing appropriate dress and learning a "complex ritual of etiquette"[18].

In contrast the ideal for working class women was that of the "good woman", also located within the home but "a much greater emphasis was placed upon her practical domestic skills as a housekeeper, wife and mother"[19].

These ideals of femininity did not reach their maturist expression until mid-nineteenth century, but they had their origins in the Evangelical's promotion of a "'domestic religion' centred around the 'moral influence' of the wife and mother"[20].

The years 1780-1850 were thus years in which a new order of society emerged and with it an overriding concern for social stability. It is within this context that there occurred what Thackray has called the "second revolution" in English science[21]. As he notes,

> "Until 1781 the Royal Society of London enjoyed a lonely splendour as the sole institutionalised, enduring English organisation devoted to the pursuit and publication of natural knowledge. Sixty years later the scene was crowded beyond recognition, with 16 metropolitan disciplinary societies..., at least 16 provincial societies covering the whole of science, and over two dozen provincial disciplinary societies..."[22]

Traditional accounts of this expansion of scientific interest during this period suggest that "science proliferated in the nineteenth century in direct response to technical problems created by the new production processes of the period".[23] However, studies in the social history of British science have argued strongly for a cultural explanation for the growth in interest in natural knowledge and the consequent development of scientific knowledge.

The popularisation of science was evident in the seventeenth and eighteenth centuries with books addressed to "Gentlemen and Ladies" covering principally the sciences of astronomy, mathematics and experimental philosophy[24]. For women of the leisured classes, science, particularly the sciences of astronomy and natural history had been a pursuit of growing popularity since the middle of the seventeenth century[25]. However, towards the end of the eighteenth century a shift in the social structure of science was occuring with the increasing representation of the new middle classes defined as the clergy, the professions, merchants and civil servants, and a corresponding decline in the numbers of those doing science who had their family origins in the upper class[26]. That science gradually became an aspect of bourgeois culture rather than aristocratic culture has been explained with reference to the geographical and social isolation of the "newly prosperous merchants, manufacturers and tradesmen" struggling to create an identity for themselves in the rapidly expanding cities beset by innumerable social problems[27]. Berman argues that the pursuit of science acted as an entrance to an elite culture as "the expression of an elite in industrial towns aspiring to more fashionable circles"[28]. Whilst in Shapin and Thackray's view, science acted as the representation and expression of an alternative culture "for groups barred from or hostile towards more traditional pursuits and institutions"[29]. In either interpretation the pursuit of science had consequences in terms of upward mobility[30] and for the consolidation of elite circles in the local setting.

Inkster argues that the "rise and role of a popular science culture in Britain" can be explained by the need for marginal groups in society, that is those "neither overtly of the capitalists and often decidedly not of the working masses" to secure "a social identity and feeling of belonging"[31]. In this view he clearly agrees with Shapin and Thackray in their conclusion that

> "The culture of science...served two distinct, complementary functions in the unfamiliar context. First it became an affirmation in cultural terms for the new economic and social order...Second, participation in science might serve to demarcate those in the local setting who cultivated it from those who followed no cultural pursuit at all; or those who argued (or assumed) that deliberate culture was unnecessary for the main business at hand, the achieving of wealth"[32].

The Literary and Philosophical Societies aimed to bring together "manufacturers, scientists and men of letters"[33], which in Manchester at least served the further aim of reducing the "cultural disparity between the province and the metropolis"[34]. In Manchester the leading elite of the "Lit and Phil" had their power bases in the Infirmary and the Dissenting community - particularly the Unitarian and the Quaker communities[35]. By the 1820s members from the business community were to join them.

Affiliation to the middle classes and dissenting religious views was characteristic of provincial science in general. Of forty-six individuals identified as members of the audience to the leading science lecturers in Sheffield in the years 1806-07, for example, ten were women and of the thirty-six men,

> "many were yet at the beginning of their career and nearly all showed upward occupational mobility. Altogether twenty-two became merchants or manufacturers of some description whilst eleven were of the professional and service groups. A very large proportion were Unitarians, twenty-one in all and of the remaining five known religious affiliations, one was a Quaker, another...a committed Deist"[36].

That natural knowledge appealed to such social groups for the legitimation of their social position has been explained with reference not only to the utility of science but, more importantly, to its religious and other social functions. Several historians of this period argue that the "congruence of science with certain religious values" and the progressive aspects of scientific thought were as important, if not more important for the development of a scientific culture as the appeals of utility[37]. Thackray distinguished seven reasons for the specific choice of science by the members of the Manchester "Lit and Phil";

> "it's possibilities as polite knowledge, as rational entertainment, as theological instruction, as professional occupation, as technological agent, as value transcendent pursuit and as intellectual ratifier of a new world order"[38].

Other cultural modes such as art, music and literature could satisfy needs for polite knowledge, value-transcendent pursuit and even professional occupation or rational entertainment, but, "as theological instruction, as technological agent and especially as intellectual ratifier of the new world order, natural knowledge commanded cognitive domains closed off from these other forms"[39].

That science became the dominant cultural expression of leading industrial elites does not mean that as a form of knowledge or a means of entertainment it was only available to the bourgeoisie. There is evidence of an interest in science among the lower classes and science was a feature of radical working class culture, particularly from the 1830s[40]. However, Russell notes that the availability of scientific knowledge to the working classes was generally restricted to those who could read and to those who had access to scientific texts[41]. The Mechanics Institute movement in the 1830s did offer greater opportunities to artisans, operatives and mechanics to receive some kind of education in science. These Institutes were "in general organised by interested members of the middle classes for specified sectors of the working-classes"[42] and offered an elementary science curriculum comprising most often the mathematical and physical sciences. Shapin and Barnes have explained the motivation behind the establishment of the Mechanics Institutes as one of social control. As noted earlier a predominant concern of the period was with social stability. Evidence of drunkenness, crime, gambling and prostitution amongst the "lower orders" led for many calls for the education of these classes "to raise a new race of working people - respectful, cheerful, hardworking, loyal, pacific and religious"[43]. A common explanation for the establishment of education for the working classes in the nineteenth century is thus one of social control. More controversial is the question of whether science education was established in the Mechanics Institutes (and schools) for the same reasons.

Thackray notes that as rational entertainment science was advocated for the sons of the elite in Manchester as an alternative to "conviviality and dissipation"[44]. Shapin and Barnes argue that in the Mechanics Institutes the dominant conception of science as "hard, factual, solid and enduring, in no way tentative or revisable"[45], was offered to the artisans and mechanics as an alternative and concrete moral authority. In that the Mechanics Institutes failed to attract those for whom they were intended, they also failed in their attempt "to modify the consciousness of the working classes to any significant degree"[46]. In criticising the argument of Shapin and Barnes, Russell notes that the curricula of the Mechanics Institutes was not only restricted to the "hard, factual and solid", and that there may have been good pedagogical reasons for dwelling less on theory and concentrating on fact. He also points out, as do Shapin and Barnes that not all sections of the bourgeoisie welcomed science education for the working classes and of those who did, Russell favours arguments concerning the utility and progress of science rather than those of social control.[47] Evidently, firm conclusions regarding the social control aspects of the science curriculum of the Mechanics Institutes cannot be made here - although it is a thesis worth further investigation. What is unanimous among historians is that after an initial enthusiastic response the Institutes failed to attract the audience for whom they were designed and by the 1850s,

> "the membership had largely ceased to be composed of working-men, who were replaced by clerks and apprentices. At the same time the educational side was subordinated to the recreational, and definite courses of instruction gave way to occasional popular lectures"[48].

In the late eighteenth century and early nineteenth century science thus served rational, religious, economic and social advancement purposes. As the nineteenth century progressed science was increasingly identified with universal and objective knowledge. Within the various provincial and London societies an a-political and value-transcendent conception of science had been seen as a means of uniting people of otherwise different political views[49]. In this way science, unlike any other knowledge form could claim objective knowledge[50]. In 1831 the British Association for the Advancement of Science was formed. Its voice, Morrell and Thackray argue was "the most powerful voice speaking for the scientific clerisy in the 1830s and 1840s"[51]. In spite of the factional identity of its leaders - mostly Liberal Anglican or Broad Church with their power bases in Cambridge and the Royal Astronomical and Geographical Societies - the British Association was able to "proclaim a universalist message" because the particular ideology of science which it articulated was able to serve the interests of groups of differing political and religious views[52]. This ideology rested on

> "the deliberate creation of boundaries between natural and religious or political knowledge, the conceptualisation of science as a sharply edged and value-neutral domain of knowledge, the subordination of the biological and social to the physical sciences (and) the harnessing of a rhetoric of science, technology and progress"[53].

A hierarchy of science thus began to emerge at this time with the mathematical and physical sciences at the top.

Concurrent with this consolidation within science was the decline of science culture. As Inkster notes,

> "as science entered a rapidly cumulative stage, in which frontier discoveries involved a mass of prior, often esoteric and implied knowledge, so it became increasingly inaccessible and diffuse"[54].

The earlier functions of science as polite culture and rational entertainment declined. Also, as the social order of the industrial cities began to settle and as there occurred a greater acceptance of "outsiders" into the inside, there was less need "for an intellectual system which could serve to legitimise their previous marginal position"[55].

Thus, prior to its institutionalisation in schools and universities, science in the 1830s was taking on a definition as universal and value neutral knowledge. Its earlier associations with utility were being tempered by the emphasis on its abstractness and as an independent body of knowledge. The tension between science as technology and science as an intellectual entertainment was one that was to grow more acute in the later decades of the nineteenth century[56]. With the promotion of science as "truth" went a hierarchical organisation of scientific knowledge with that of an "exact" nature - physics and chemistry - at the top[57].

The participation of women in the scientific culture.

These aspects of the culture of science and the Industrial Revolution have been dealt with in some detail following the argument of Bridenthal and Koonz that "women must be seen within the complexity of their specific cultural contexts"[58]. In order to understand the nature of women's participation in the science culture it thus becomes necessary to know something of its characteristics.

The function of science as affirming a new economic and social order had specific consequences for women, not generally discussed in historical analyses of the culture of science. For women access to science was limited by elements of the same cultural milieu which ensured the openness of science for many men. Hall notes that:

> "1780 - 1850 was the age of societies, when societies were formed in aid of every possible cause. These societies ranged from ones with a primarily political orientation to those concerned with commercial activities, self-education in its broadest sense and philanthropic works. It was exceedingly difficult for women to be involved in any of these except the philanthropic and even there they were encouraged to participate privately and informally rather than being engaged in public activities".[59]

As has been discussed above, there was no exception to this trend towards the formation of societies within science. In Manchester alone, between 1780 and 1850, the Literary and Philosophical Society (1781), the Natural History Society (1821), the Statistical Society (1834), and the Manchester Geological Society (1830) had been formed[60]. Nationally, between the years 1788 - 1839 twelve specialised scientific societies had been formed, including the Linnean Society (1788), the Geological Society (1807) and the Astronomical Society (1820)[61]. Women were generally excluded from the growing number of these scientific societies and associations. In Manchester for example, women could not belong to the "Lit and Phil", but as wives and daughters of members they may have been allowed access to special collections or exhibitions[62]. The new building for the Manchester Royal Institution included a ladies ante room denoting women's outsider status. Women occasionally published papers in the Transactions and Journals of the Linnean Society, but were not actually admitted to it until 1904[64]. All other societies excluded women completely except the Botanical Society of London (1836 - 1850), the Zoological Society of London (1826) and the Entomological Society of London (1833)[65]. In practice even in these societies women were under-represented. They only accounted for ten per cent of the founding members of the Botanical Society, falling to six per cent by 1839. This represented only "a fraction of the total who were active in the field in this period"[66]. Similarly, only one woman was a founding member of the Entomological Society of London. In 1834 there was only one woman among 126 men, a situation little improved by 1840 when the male membership had risen to 216, but women were only represented by Mrs. Frederick Hope, wife of the Reverend F. Hope, a founding member and president of the Entomological Society (1835 - 1837) and a founding member of the Zoological Society[67]. More women were involved in the Zoological Society - 69 members in 1830, 168 in 1835, but their numbers only represented about two per cent of the total membership[68]. As outside observers women did form part of the fashionable audience which flocked to the Royal Institution of London and its lectures on experimental philosophy in the first years of the nineteenth century[69]. When the BAAS was formed, women crowded out the lectures at the annual meetings, in one instance to such an extent that "members (men) were excluded and forced to promenade the lobbies and staircases"[70]. Initially attempts had been made to exclude women altogether from the BAAS, but financial considerations made this undesirable[71]. Owing to this,

> "women thus became central to the style and success of the British Association though irrelevant to its manifest purposes and debarred from any formal say in its government"[72] (my emphasis)

The Mechanics Institutes, as well as class specific in their original intention, were also sex specific. Women "had to struggle to enter the Institutes and were admitted somewhat reluctantly"[73]. Even on gaining admission they only enjoyed a subordinate position akin with children[74]. The radical institutes were no better. Men "urged women's classes on the grounds that 'young women should be taught the duties of housewifery'"[75]. Later, the founders of the Manchester Hall of Science were defending their decision to provide instruction for women on the grounds that "numerous scenes of domestic thriftlessness, discomfort and contention would thereby be eliminated"[76] - an argument of social control, but with little evidence of any scientific instruction. Indeed, there is little evidence of participation by working class women in science. It is possible that the radical Owenite movement offered women opportunities to explore scientific interests[77] but, methodological problems aside[78], it could be concluded that, as for the majority of working class men, poor provision of basic education with high rates of illiteracy restricted what few opportunities there might have been to follow developments in science[79].

There is thus little evidence that science offered to women the same opportunities for social mobility and cultural enhancement through participation in one of the many scientific societies established at this time. Even in those societies in which women were not constitutionally excluded, self-exclusion appears to have operated. Such a phenomenon can be explained by the increasing advancement of the "domestic ideal" such that women's participation in public life - including the public side of science - became unthinkable[80]. Undoubtedly, as noted above, women were interested in scientific topics, but their private and domestic role shaped the possibilities and limitations of that interest.

As a direct result of the industrial revolution, farmers, merchants, manufacturers, shopkeepers and tradesmen were able to enjoy a greater wealth and the comforts of a lifestyle unknown to their predecessors. Such an increase in wealth,

> "brought new standards of luxury and new ideas of refinement which prevented women in the business and trading classes taking any further share in their husbands concerns and experience in such matters was lost"[81].

Women of these classes had leisure and wealth unknown to them before. Among certain sections of society this gave rise to concern about the nature of girls' education. For working class girls, education, later in the century, was advocated "as a solution to many of the problems of the working class family" such as drunkenness, gambling and prostitution [82]. Through education the ideal of the "good wife and mother" could be upheld[83].

For middle class girls the emphasis was different. The Evangelicals particularly were critical of aristocratic lifestyles and the emulation of such lifestyles by the newly wealthy classes. They wished to define "for the middle ranks a way of life best suited to their affluence and leisure"[84]. For women the stress was upon the need for a reform of education, exchanging for the frivolous smattering of accomplishments characteristic of a "refined" education for girls, a more solid, rational and moral education, conforming to the Evangelical ideal of woman as "modest, unassuming, unaffected and rational"[85]. Science as illustrative of the order and harmony of the Universe and God's creation was a particularly suitable study. Also as a form of recreation it conformed to the requirement that it should be rational, non-sensual and moral[86].

The late eighteenth century saw an expansion in the production of books with scientific themes specifically for women and children.

Prior to these years publishers had not made any special provision for children's literature. Books for children that were written earlier in the century were more often the result of a leisure pursuit of the publisher himself, or were "commissioned from hack writers"[87]. Once publishers believed that children's books were a viable proposition, a stream of books were produced and women were among the most prolific writers[88]. The greater leisure of women of "middling ranks" and the popular interest in Linneaus's system of botanical classification at the end of the eighteenth century also provided a new market for publishers. Many books appeared in English rather than the traditional and scholarly Latin, implying that they were designed to cater for "an extensive new readership among people without any formal academic background"[89]. Among the texts appearing on natural history it was evident that many were written specifically for women. For example, in his preface to "Botanical Arrangements" (c.1770), William Withering wrote:

> "From an apprehension that botany in an English dress would become a favourite amusement with the ladies, many of whom are considerable proficients in the study, in spite of every difficulty, it was thought proper to drop the sexual distinctions in the classes and orders."[90]

Women were caught in a contradiction. The Linnean system of plant classification was widely accepted in England by this time because of its simplicity and thus because many people felt they could "keep abreast of science in this one area at least"[91]. The problem was that it was a sexual system of classification and, as such, potentially shocking to the unworldly, private, domestic woman.

In many texts addressed to women dealing with natural history, the "raw and bloody underside" of nature was concealed and the aesthetic top-side emphasised[92]. In non-botanical fields, however, the problems of access women faced, were more to do with a lack of background education, particularly in mathematics. Brody notes that the "style and prerequisites" of even easy, non-mathematical popular scientific works was "a formidable handicap for women"[93]. Thus, if they were to receive any beneficial form of education in science, texts had to be very elementary, requiring little or no previous knowledge and therefore a non-mathematical treatment, presented in simple and easy style[94]. Such texts did begin to appear by the late eighteenth century, many of them written by women specifically for a female readership[95].

Women science writers

It is interesting to note some of the characteristics of the women who wrote these texts.

The first point to note is that relationship to men, either as fathers, brothers, husbands, cousins or uncles, who actively participated in the scientific enterprise seems to have been an important key to entry. This seems to have been the case for women's participation in science in general. Allen, in his study of the Botanical Society of London, noted that of the women members

> "an impressively high proportion prove to have had a husband or a brother or a father or uncle or at the very least a cousin who also had a well-developed interest in science, if not necessarily in botany"[96].

Similarly, Shteir has noted women who, as daughters or wives of botanists developed their own interest either through observing, collecting, illustrating botanical specimens, or by publishing books on botany and other aspects of natural history[97].

Another important consideration, aside from male influence, were the possibilities afforded to some middle and upper-class women, by their participation in the literary salons of the day[98]. Many of the more celebrated writers were known to each other, forming a small and intimate literary circle with London as their base[99]. For example, Mrs. Anna Laetitia Barbauld[100], well known for her children's books, had a "warm friendship" with Hannah More[101] the Evangelical propagandist, was acquainted with Maria Edgeworth[102] and Harriet Martineau[103], who was herself intimate with Jane Marcet[104] and a friend of Jane London[105].

Of authors on which there is information, by far the majority were married and of the middle classes. Several were married to merchants or were the daughters of merchants[106]. Many had strong religious connections through their families and, or husbands[107] and several were engaged in teaching either by running their own schools[108], as governesses[109] or as part of their philanthropical work[110].

That women could, and did, write popular books on science can be explained largely by the fact that writing was a private activity which could be done within the confines of one's own home in contrast to the public arena of the scientific society. It was thus an activity which was compatible with other domestic occupations and with an expected role of women as educators of children. Importantly writing on scientific topics required no institutional support, or even special apparatus beyond pen and paper[111]. This has been a crucial determinant of the form of women's participation in science, and continues to be so[112].

Writing works of a botanical nature seemed particularly attractive to women. First of all nature had peculiar pedagogical appeal. Thwaite argues that the popular use of nature to introduce "a sense of wonder and reverence for the work of creation" reflected a pedagogical shift towards the teachings of Rousseau, who stressed the importance of a feeling for the wonders of nature[113]. The study of nature was also cheap, requiring little or no equipment and was eminently suited to illuminate the recreational walks common at this time[114]. The collection of natural objects encouraged by such work could show an "order underlying the seemingly chaotic phenomena of the natural world"[115].

Secondly, women had material for such books on their doorstep. Unlike their brothers who could roam the world for interesting specimens, women had to rest content within the confines of their local environs; but it was an environs which was rich with botanical material. It was not until later in the century that women threw aside convention and travelled around the world seeking new and unusual plants[116].

Thirdly, Brody argues that women showed a preference for the life sciences because their general lack of mathematical understanding handicapped their attempts to popularise other branches of science through their books[117]. Finally, writing on science gave women the opportunity to earn money at a time when it was not at all acceptable for women to work for financial reward[118]. Several women published books of a scientific nature to relieve financial difficulties[119].

Women writing on science.

Evident in much of the writing by women is a particular view of the place of science within education and the function of science education for girls. In short, scientific topics were the medium by which moral and religious sentiments could be imparted.

In the turn to religion experienced from the late eighteenth century onwards, religious groups, particularly those of a dissenting nature championed education as "central to a broad programme of social reform"[120]. Amongst those who wished to see educational reform, knowledge was not seen as an "end in itself, but the means to create understanding and self discipline"[121]. It was within this framework that many women introduced scientific topics into their writing. Sarah Trimmer, who was inspired by the work of Anna Barbauld, stated in her preface to "An Easy Introduction to the knowledge of Nature and reading the Holy Scriptures" (1780), that:

> "I therefore thought that a book containing a kind of general survey of the works of nature would be very useful as a means to open the mind by gradual steps, to the knowledge of the Supreme Being, preparatory to their reading of the Holy Scriptures".[122]

Parts one and two of the book concern themselves with topics on nature, whilst in part three, "the book of nature" gets put aside for the bible[123].

Similarly, one intention of Priscilla Wakefield in her "Introduction to Botany in a series of familiar letters with illustrative engravings" was:

> "to cultivate a taste in young persons for the study of nature, which is the most familiar means of introducing suitable ideas of the Divine Being, by exemplifying them in the order and harmony of visible creation".[124]

For girls and women there was a specific moral importance attached to the study of scientific knowledge. As Maria Edgeworth stated in her "Letters for Literary Ladies" (1795):

> "Botany has become fashionable, in time it may become useful, if it be so not already. Chemistry will follow Botany. Chemistry is a science well-suited to the

talents and situation of women; it is not a science of parade, it affords occupation and infinite variety; it demands no bodily strength; it can be pursued in retirement; it applies immediately to useful and domestic purposes: and whilst the ingenuity of the most inventive mind may in this science be exercised, there is no danger of inflaming the imagination because the mind is intent upon realities, the knowledge that is acquired is exact, and the pleasure of the pursuit is the reward for the labourer".[125]

Priscilla Wakefield wished that the study of botany:

"become a substitute for some of the trifling, not to say pernicious objects that too frequently occupy the leisure of young ladies of fashionable manners, and, by employing their faculties rationally act as an antidote to levity and idleness".[126]

Such sentiments have been quoted as evidence of the function science played as a form of social control in women's education[127]. Shteir, examining women and botany, notes that

"it is not difficult to argue that botanical study for women in England during the eighteenth and nineteenth centuries served, and in some quarters was intended to serve as a form of social control, substituting innocuous activities and attitudes for others more threatening to conventional views of womankind".[128]

However other aspects of women's writing on science show that it served other important functions for the women themselves and for their intended female audience.

It has been claimed that "few women with scientific aspirations had feminist aspirations"[129], and certainly the evidence would suggest this to be the case. Women such as Maria Edgeworth urged the reform of women's education so that they be more suitably trained to exercise their moral influence as "daughters, wives, mothers and mistresses of families"[130], for it was this that was a woman's profession. She noted that a woman's influence

"must be private....the female influence is a necessary and important link, which you cannot break without destroying the whole".[131]

Women were thus to be educated not only for their self-enlightenment but, more importantly, to fulfil their domestic role better, for as Maria Edgeworth said, "can women of such uncultivated understandings make such wives or such mothers?"[132]

The promotion of women's interests was anathema to women such as Hannah More and Anna Barbauld, both implying a connection with Jacobin radicalism and upsetting their own notions of a particular balance between the sexes. Mary Wollstonecraft was their contemporary, but she was too radical for them. Of Wollstonecraft's book, "Hannah More wrote that there was something so ridiculous in the very title that she had no intention of reading (it)".[135]

Anna Barbauld refused to work on a woman-only journal, replying to Maria Edgeworth's invitation - who, interestingly did favour this enterprise in spite of her views on women's education - that

> "Mrs. Hannah More would not write along with you, or me and we should probably hesitate in joining Miss Hays (a Wollstonecraftian) or, if she were living, Mrs. Godwin (Mary Wollstonecraft)".[134]

Anna Barbauld also refused Mrs. Montagu's invitation to become the principal of a Ladies College that she wished to establish with the response that, "the best way for a woman to acquire knowledge is from conversation with a father or brother and by such a course of reading as they may recommend".[135]

These are not, at face value at least, feminist sentiments. However, alternative interpretations are possible. Spender, for example, argues that it was possibly a question of political strategy for women such as More and Barbauld to assert "that they did not wish to challenge men or the limits of women's sphere - while they proceeded to do so".[136] Such a strategy she argues was later employed by Emily Davis in her uncompromising belief "that women had to conform rigidly to the rules of ladylike behaviour precisely because they were challenging the fundamental idea of women's intellectual authority".[137] It could also be that such women distanced themselves from the views and initiatives of Wollstonecraft and her followers, not for anti-feminist reasons, but because their radicalism was simply <u>too</u> extreme.[138]

Although firm conclusions cannot be made on this point, two conclusions are evident from an examination of the work of women science writers. Firstly, it was not uncommon for women to be writing to share their knowledge with other women, and moreover to share it in such a way that was accessible to women who were handicapped in their education and opportunities. Margaret Bryan dedicated her book "A Compendious System of Astronomy" (1797) to the pupils at her girls' school. It consisted of the lectures on astronomy which she originally wrote for them and was "intended to render subjects generally thought obscure, clear to the understanding of young people".[139] The religious motivation was evident in this text, the first lecture being entirely devoted to this theme,[140] but more significant here perhaps was her effort to ensure that her lectures were "intelligible to those who have not studied the Mathematics".[141] In similar fashion, Catherine Whitwell must have had a female audience in mind in her "Astronomical Catechism; or Dialogues between a Mother and her Daughter". This book concentrated on "popularising Newtonian astronomy non-mathematically", and Whitwell assured her readers that mathematics was only necessary for pure or plane astronomy.[142] Jane Marcet addressed her "Conversations on Chemistry", "particularly to the female sex". Her intention here was to offer other women and girls the advantages she had had to learn chemistry, both by attendance at public lectures and in conversations with a friend, with whom she repeated experiments. She chose a conversational style for this work because from her own experience of learning the subject she inferred

> "that familiar conversation was, in studies of this kind a most useful auxiliary source of information and more especially in the female sex, whose education is seldom calculated to prepare their minds for abstract ideas and scientific language".[143]

Her book was remarkably successful and was popularly used in England and abroad. In America alone it sold more than fifteen thousand copies in the first fifty years and became a general textbook on chemistry. However, although over 160,000 copies were sold in all "the fact that this work emanated from the pen of a women was carefully withheld".[144] Mrs. Marcet did publish anonymously, but any suggestion that a woman was author was disclaimed.[145]

The popularity of "Conversations on Chemistry" was undoubtedly linked to the conversational style and Marcet's "literary adeptness coupled with a good, solid understanding of her subject".[146] Whilst the conversational mode of writing did not originate with Jane Marcet - this was first used by Fontenelle in his work "Entretiens sur la pluralitę du monde" (1686) and translated by Aphra Behn as "The Plurality of the World"[147] - Brody notes that,

> "there can be no doubt that such a popular work consisting of conversations on science exclusively between females resulted in other women also beginning to consider themselves capable of some attainment".[148]

The books of Mary Somerville (1780 - 1872) achieved an audience equal to those of Jane Marcet's. She was one of the few women to achieve an international reputation for her work.[149] In her work there is a suggestion that one motivation for writing was to enable other women to become familiar with "the laws by which the material world is governed".[150] Unlike the traditional treatment of the physical sciences, Somerville's approach in her book "On the Connexion of the Physical Sciences", which first appeared in 1834, was very original, stressing the connections between heat, light and so on. It is possible to explain this perhaps by Somerville's own lack of formal education, or possibly by a particularly "feminine" approach to the subject.

Ann Shteir , in her study of introductory botany books for and by women, suggests that in the years up to the 1860s there was a discernible feminine approach to writing.[151] The important characteristics of books by women were that they were familiar and personalised, they had a narrative element and, as noted above, they all taught or were seeking to teach something more than botanical science. This could be used either in a liberating way by women writers or in a way which reinforced the dominant ideology of femininity. Such treatment was not confined to botany as evidenced by Jane Marcet's work, or perhaps that of Maria Hack whose "Lectures at Home" published in 1841 dealt with the subjects of the discovery and manufacture of glass, refraction, microscopes and the eye. By contrast, texts directed to men or non-sex specific texts tended to be catechistic, non-narrative, with no familiar or personal elements, and no sense of the science being taught for other purposes. In short, in texts for girls, science was a means to other ends, whereas in texts for boys science was studied for its own sake. Schteir argues that it was this male model which set the pattern for the later nineteenth century introductory text-books.

The second conclusion to be drawn about women writing on scientific themes is that many writers perceived that they were treading a very fine tightrope between accepted convention and unacceptable behaviour. At the end of the eighteenth century Anne Barbauld had been softly chastised by a reviewer for "treading too much in the footsteps of the men" and was reminded that "there is sex in minds as well as in bodies".[152]

Margaret Bryan and Jane Marcet openly recognised that by publishing books of not just a scientific, but of a learned nature they were treading on dangerous ground. Learning in women was not encouraged, suggesting as it did a lack of femininity.[153] Thus was Jane Marcet, in her "Conversations on Chemistry" apprehensive that her work would not be received well, involved as it was with a subject "that might be considered by some....as unsuited to the ordinary pursuits of her sex".[154] Margaret Bryan craved "the indulgence of a discriminating public" almost defiant in her assertion that,

> "I have not presumptuously offered opinions, without having previously digested those of the best writers on the subject; or attempted to elucidate without due observation of the principles of this science. For this mental exertion I expect some countenance from those whose extensive learning and liberality lead them to judge impartially; for they, rising superior to the false and vulgar prejudices of many, who suppose these subjects too sublime for female introspection, (ascribing to mental powers the feebleness which characterises the constitution), invalidate the idea by affording all laudable exertions their avowed patronage - acknowledging truth, although enfeebled by female attire".[155]

It is interesting to note Bryan's acceptance of the physical inferiority of women, but her insistence that this is not necessarily matched by a weakness of the mind. Similarly, it is perhaps an echo of her frustrations as a woman debarred from the activities and ideas of the public realm that led Marcet to express the view that through reading her work, other women

> "may obtain such a knowledge of chemistry as will not only throw an interest on the common occurances

> of life, but will enlarge the sphere of her ideas and render the contemplation of nature a source of delightful instruction".[156]

Women and science and the scientific education of girls.

From the late eighteenth century, cultural forces were limiting both the nature of women's participation in science and the type of knowledge areas deemed suitable for them. Education in science was encouraged not for the knowledge itself, but for its example of discipline and the rational order of the world. The one area of the scientific enterprise in which women were active was in the popularisation of science through their many books on scientific topics. Whilst overt feminist sentiments are not in evidence, it is the case that some women writers actively sought to share their knowledge with other women. For all women ambiguities existed in their pursuit of science. Learnedness in women was not compatible with conventional ideals of femininity during this period.

Thus, in the period when science was taking shape as a specialist pursuit, and when a particular concept of science was emerging as the "paradigm case" and source of "cognitive authority"[157] women were an interested and active but marginal and increasingly marginalised group.

Shteir is right when she says that women's contributions to science should both be acknowledged and re-valued.[158] She attempts to do this for the science of botany arguing that women played an important role as "cultivators of science".[159] However as both Shteir and Brody show in their discussions of women in science during this period, women worked and produced under severe handicaps.

Women did not have the same access to science as did men. Brody notes that women lacked a solid groundwork in mathematics which made their own education in science difficult and thus their attempts to pass on knowledge incorrect at times.[160] Such a lack of solid education in mathematics must have been the case for many men at the time as well, but it is arguable that men had greater formal and informal opportunities to remedy this situation than did women.[161] In this regard women's exclusion from the scientific societies could have only compounded these problems. However the choice of their scientific subjects was limited as much by their domestic environment and the discouragement of learnedness in women as by any educational disadvantage. Women thus tended to confine themselves to the life-sciences or very elementary studies in the physical sciences because these did not require much or any mathematical competence.

What is important here, and significant for the investigation of education in science for girls is the legacy these social factors had for the association between women and science. Two points are of significance here.

Firstly, as social studies of science have shown, political and religious beliefs, partisan and class interests, have affected the representation of the physical world.[162] Women, as a marginal group in science and associated with the private, domestic world, were not involved in the negotiation of scientific meaning. Even if it could be said that women's interests were confined principally to the domestic world, such concerns were not in the field of negotiation - unlike later in the century when such interests defined a specific form of feminism and promoted a specific conception of science: domestic science.

Secondly, confined to the private sphere in contrast to the public world of business, where rationality took on specific meanings in relation to efficiency[163], the age-old association between women and irrationality was reinforced. As the natural sciences increasingly took on connotations of abstract, universal and value-neutral knowledge, with the mathematical and physical sciences at the top of a scientific hierarchy, so did women's socially determined interest in the life sciences locate them at the lower end of the scientific ladder.[164] Science text-books which divorced the study of scientific phenomena from social concerns increasingly took the place of texts which situated scientific knowledge and its study in a broader context. As this occured, the latter, associated as they were with a specifically feminine approach to writing, were regarded as inferior. Such was the power of the "male" model that women chose, or were forced, to abandon what had been a popular and well-received style of presentation.[165]

Thus, prior to the establishment of science in school curricula during the latter half of the nineteenth century popular ideas about the nature and limits of science education suitable for women had developed.

In the following two chapters the development of science education for girls will be discussed. In view of this early period two questions need to be investigated. Firstly, how was science introduced into the various types of schooling available to girls and why? Secondly, how was science portrayed and what functions did science education serve?

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80. It has yet to be explored how far women's absence from science compared with their absence from other fields at this time. The suggestion here is that all areas of knowledge excluded women from their more public aspects, but detailed information on this would be interesting in view of the contemporary debates on the masculinity of science.
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101. Hannah More, 1745-1833. Remembered as a religious writer and Evangelical propagandist.
102. Maria Edgeworth, 1767-1849. Daughter of Richard Lovell Edgeworth and Anna Maria Elers. Her father was controversially well-known for his views on education. Her half-brother, Michael Pakenham Edgeworth, was a botanist. Maria Edgeworth remained single, but took a large share in the life of her family. She wrote mainly for children, but also "Letters to Literary Ladies", a defence of female education.

103. Harriet Martineau, 1802-1876. Described by the Dictionary of National Biography as, "a miscellaneous writer". She was from a Unitarian family, her father a manufacturer. Her work includes novels, essays, travel books, translations and religious works.

104. Jane Marcet (nee Haldimand), 1769-1858. The only daughter of a rich Swiss merchant, she married in 1799 to Dr. Alexander Marcet, a physician. "She wrote familiarly on scientific subjects at a time when simple scientific text-books were almost unknown" (Dictionary of National Biolgraphy). Her works include: 1806, Conversations on Chemistry; 1816, Conversations on Political Economy; 1819, Conversations on Natural Philosophy; 1829, Conversations on Vegetable Physiology.

105. Jane Loudon, (nee Webb), 1807-1858. Married John Claudius Loudon, a landscape gardener and horticultural writer. She began to write botanical books of a popular character when her husband was in debt. Her books include: 1841, Ladies Companion to the Flower Garden; 1841, The first book of botany; 1842, The year book of natural history for young persons; 1850, The entertaining naturalist; 1854, Facts from the world of nature.

106. The father of Jane Marcet was a merchant; Elizabeth Blackwell (nee Blackrie) (died 1758), the botanical illustrater, was the daughter of an Aberdeen stocking merchant; Mrs. Charlotte Smith (1749-1806) was married to the son of a West India merchant; Patricia Wakefield (nee Bell) (1751-1832) was married to Edward Wakefield, a merchant; Mary Roberts (single) (1788-1864) was the daughter of a merchant; Anne Pratt (1806-1893,later Mrs. Pearless) was the daughter of a grocer.

107. Sarah Trimmer (nee Kirby) (1741-1810) was extremely religious, and organised Sunday schools for poor children and was also connected with the S.P.C.K.; Patricia Wakefield, Maria Hack (nee Barton, 1778?-1844) and Mary Roberts, were all Quakers, or brought up as Quakers. The husbands of Anne Laetitia Barbauld, Maria Elizabeth Jackson (early nineteenth century) and Margaret Gatty (nee Scott) (1809-1873) were all clergymen, as was the brother of Elizabeth Mayo (1793-1865).

108. Margaret Bryan ran a school for girls first at Blackheath and then at Margate around the turn of the eighteenth and nineteenth centuries; Elizabeth Mayo helped in her brother's school until his death in 1846. She then worked for the Home and Colonial School Society.

109. Mrs. Mary Cockle (pseudonym) who wrote Moral truths and studies in Natural History, was governess to the Misses Fitzclarence.

110. For example, Maria Edgeworth and Sarah Trimmer.

111. This is a point Virginia Woolf makes about women writing in general in her essay A Room of One's Own, Panther Books, London, 1978, pp.62-63.

112. Rossiter makes the point that the role of textbook or science writer is one "that is now taken for granted, but one that, since it requires little institutional support has continued to attract women scientists". Rossiter, M.W., Women Scientists in America - Struggles and Strategies to 1940, John Hopkins University Press, 1982, p.7.

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119. For example Elizabeth Blackwell started her work on "A curious herbal" to relieve severe financial difficulties; Charlotte Smith took up writing when her husband was imprisoned for debt - with 12 children in all, and finally separated from her husband, she produced one novel a year. Jane Loudon began to write botanical books when her husband got into debt, after his death writing was the means by which she supported herself and her daughter.

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135. ibid., p.62.
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137. ibid.
138. My thanks to Ann Shteir for suggesting this point to me.
139. Bryan, M., A Compendious System of Astronomy, 3rd Edn., Wynne and Scholey, 1805, p.vii.
140. The lecture opened with the statement that, "Natural objects when properly contemplated, continually admonish us in the important science of Divine Wisdom, leading us to consider our situation in this sublunary state, our connections and dependencies; from which we learn the duties required of us and the exertions we are capable of making", ibid., p.1.
141. The full title of the book was "A Compendious System of Astronomy in which the principles of that Science are clearly elucidated, so as to be intelligible to those who have not studied Mathematics".
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144. Spender, op.cit.
145. Green, J.H.S., "Mrs. Marcet and her 'Conversations on Chemistry'", New Scientist, October, 9, 1958. Smith, E.F., Old Chemistries, McGraw Hill, New York, 1927, pp.64-71.
146. Brody, op.cit., p.22.
147. Meyer, op.cit., p.17.
148. Brody, op.cit., p.22.
149. During her life time Mary Somerville was elected as an honorary member of the Royal Astronomical Society; the Royal Academy at Dublin; the

Bristol Philosophical Institution; the Societe de Physique et d'Histoire Naturelle of Geneva; the Geographical and Statistical Society, New York; the Academy of Natural Science at Florence; the Accademia Tiberiana (Italy); an Associate of, the College of Risurgenti (Italy); the Imperial and Royal Academy of Literature and Art at Arezzo (Italy); Italian Geographical Society. She was awarded the Victoria Medal by the Royal Geographical Society for her book "Physical Geography"; she was awarded the first gold medal of the Geographical Society at Florence. For full biographical details, see: Somerville, M.S., Personal Recollections of Mary Somerville, John Murray, 1873; Patterson, E.C., Mary Somerville and the cultivation of science, 1815-1840, Archives Internationales d'histoire des ideas, 102, Boston, Mass., 1983.

150. Quoted in Spender, op.cit., p.171.
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152. Rodgers, op.cit., pp.59-60.
153. This is evident in the editorial address of The Ladies Magazine - a journal in circulation in the 1820s. A fair amount of scientific questions and topics were found in these. In the address to volume two, 1821, the editor wrote that "we do not boast that we are equal in profundity of speculation to those who cater almost exclusively for male guests, nor indeed is it necessary that we should treat our fair readers with abtruse speculations in philosophy, theological disputes or political disquisitions. They cannot be expected to enter with zeal into such topics; but they may be allowed to skim the surface of science, trace its application to the useful purpose of ordinary life....". In similar vein, the address to volume eight, 1827, stated, "avoiding the subtleties of metaphysics and the abstruseness of complicated science, we have principally attended to polite and elegant learning".
154. Marcet, op.cit., p.ix.
155. Bryan, op.cit., p.ix-x.
156. Quoted in Green, op.cit., p.ix-x.
157. Barnes, B., and Edge, D., Knowledge in context - readings in the sociology of science, Open University Press, Milton Keynes, 1982, p.2.
158. Shteir , 1984, op.cit., p.73.
159. ibid.
160. Brody, op.cit., p.19.

161. For example, the brother of Mary Somerville had lessons in Euclid and Algebra, she did not.

162. As Allen notes of the Botanical Society "It was a society of outsiders from a scientific point of view as well. As if in deliberate defiance, it made up for its exclusion from the social mainstream by nailing its colours to a heterodoxy like other bodies of its kind. Just as its contemporary and half sister, the Meteorological Society of London energetically played with the view that climate was influenced by the planets, so the Botanical Society aggressively espoused the 'natural system', the new system of classification still then in the process of pushing aside the 'artificial system' long doggedly defended by the disciples of Linneaus. A society that saw itself as on the side of progress, could hardly have been expected to choose otherwise; at the same time, even if the members had not been convinced of their correctness in this matter conceptually they would surely have found in the struggle to dethrone a shamelessly contrived ordering of nature, so deeply identified with the 'Establishment' in their discipline, an emotional appeal which rang resoundingly in tune with their more broadly liberal sympathies". Allen, 1980, op.cit., p.248.

163. See, Morgan, D., "Men, masculinity and the process of sociological enquiry", in Roberts, H., (ed.), Doing Feminist Research, R.K.P., 1981, pp.88-113, (p.93).

164. It is interesting to note here the type of books women were publishing from the 1830s onwards. Most of these appeared to deal with topics in natural history. Although diversification is apparant - into fields of conchology, mineralogy, zoology for example - the emphasis is on botanical texts. Arguably women's exclusion from other fields of scientific discourse was being reinforced by increasing specialisation with the resultant greater technical language and thus greater difficulty of access to the amateur.

165. Shteir , (1985, op.cit.) makes this point in relation to "Botany for Novices" written by Lydia Becker, the suffrage compaigner, and published in 1864. This was not gender specific, had no "spill-over" into other aspects of life, was written in the third person rather than in the personalised style of former women's writing. Schteir argues that the lack of narrative style can be explained by the identification of narrative with the feminine, and thus amateur. As a feminist wishing to see more women enter into public and professional life, it is likely that Lydia Becker would have adopted the male model seeing it as more likely to be successful.

3. Science education for girls in the elementary and post elementary schools of the nineteenth century.

Introduction.

The following two chapters consider science education in the various types of schools which were established during the nineteenth century in England. Chapter three is concerned specifically with educational institutions catering for the working classes, whilst chapter four examines the establishment and development of science education in schools for middle class girls. This distinction on class lines is necessary. Education throughout the nineteenth century was intentionally and unambiguously class specific[1]. Education for the working classes was not designed to promote equality or social mobility. Indeed, its prime function appears to have been the opposite of attempting to maintain a rigid and hierarchical class structure[2]. The distinction between elementary and secondary education at this time did not refer to the age of pupils, nor to a sense of continually progressive education, but rather to the class of the pupils and the type of education they were most likely to receive.

A consideration of class is thus important and necessary when investigating the provision of science education for girls. However, it is not sufficient. Educational provision was both class and gender specific. The bourgeois gender ideology of femininity discussed above, which stressed the domestic role of women was significant in the development of educational provision for girls of both the working classes and the middle classes[3]. It is thus within the contexts of class and gender that the possibilities for the scientific education of girls must be discussed.

In the early years of state educational provision, intended to furnish a "useful education for the children of the poorer classes throughout England and Wales"[4], support for the teaching of science came from dissociated individuals who in the 1850s "independently and from a variety of standpoints had converged upon what appeared to be a common view of the most appropriate curriculum for elementary schools"[5]. This decade saw the rise and decline of a movement for the teaching of science in the elementary curriculum. By the 1860s, because of a conflict of aims which existed amongst the chief advocates of science as an educational subject, the movement was not strong enough to withstand the blow of the 1862

Revised Code, which by introducing the sytem of payment by results effectively reduced the curriculum to the three "'Rs" and needlework for girls[6]. The focus of interest of this chapter is not so much on the personalities or in the movement itself, but in investigating to what extent, if at all, the early science education of working class children was sex specific. This will involve an examination of developments before and after the 1862 Code and some consideration of post elementary education.

Conceptions of education for the working classes in the nineteenth century and their influence on the science curriculum.

Historians of this period of education have understood the emergence and development of state support for elementary education as being intimately connected with the desire to promote law, order and social stability[7]. As Johnson has identified, there were four themes which recurred in the educational writing of the early Victorian period and of the reports of the school inspectors:

> "the potential benevolence of economic change....an indictment of the patterns of working class behaviour, an emphasis on the need for some substitute for the abrogated functions of the working class parent; an insistent demand for close control over that substitute - the elementary school and the elementary school teacher"[8].

He thus concludes,

> "the early Victorian obsession with the education of the poor is best understood as a concern about authority, about power, about the assertion of....control"[9].

The curriculum thus tended to be governed by the twin concerns of morality and utility complementing the social goals of social order and stability. Those who brought education to the "labouring poor" - the bourgeoisie - brought with them their own conceptions of morality and authority. Education was seized upon by Victorian patriarchs, philanthropists and religious men and women as being the corrective to all forms of social ills that they perceived in the early decades of the nineteenth century[10]. Not least among these was the failure of the working class family in all aspects of domestic relations[11]. It is here, with the bourgeois ideal of "the good woman", that it is possible to understand the desire to provide education for working class girls by male middle class reformers who doubted the necessity of education for their own daughters. As Johnson notes, the reactions of the reformers in this respect,

> "seem to have been determined quite as much by their picture of what the family should be (a conception derived no doubt from the bourgeois ideal of that institution) as by the undoubted cultural disruption faced by working people in many different industrial settings"[12].

Education was perceived as a suitable medium through which working class children could be impressed with the "bourgeois view of family functions and responsibilities"[13] and through which girls could be taught the necessary skills to fulfil the requirements of domestic service and maintaining a home.

From the early provision of education for children of the working classes a division was apparent between the education of girls and boys. As early as 1847 the Rev. Muirhead Mitchell was advocating a supply of textbooks for girls,

> "that would supply information on their own peculiar duties and the subjects likely to engage their attention in after life....A work is wanted that will teach girls their practical duties as mothers and wives"[14].

In 1863 the Rev. R. Temple was championing single sex schools on the grounds of "discipline" because "boys will make girls rude" and in "instruction" because "as girls have to sew during the afternoon it is very hard to make them work evenly with boys of the same class"[15]. Similarly, the Rev. F. Watkins reporting on schools in the Northern district remarked upon "the small proportion of girls in these schools". Rather than accept a common view that this was because the schools were "unpopular with parents", he stated his own view,

> "that the smaller number of girls is owing to another circumstance, viz. that sewing is not taught, or only by an inferior sempstress in them; and the girls are

> sent to other places where they are instructed carefully in needlework"[16].

This emphasis on needlework for girls was one of the significant curricular differences between boys and girls which was unquestioningly and freely built into the elementary school curriculum, and was tenaciously maintained throughout the century. No school could share in the annual grant from the Treasury unless in its trust deeds a clause was inserted to the effect that it would teach needlework to girls[17]. This insistence on needlework for girls certainly encroached upon the time available for other subjects. At the School of Industry at Hoxne near Eye, Suffolk, girls were not permitted to learn arithmetic[18]. At a national school in North Shields the girls were taught sewing and received prizes of pinafores and prayer books, whilst the boys in the first class were taught geography[19]. At the School of Industry at Norwood the boys spent much more time in class than the girls, who were either engaged in industrial work, which, in the case of girls meant domestic work, or needlework. This was a situation which the inspector, Seymour Tremenheere considered

> "a manifest deviation from former arrangements under which it was intended that the time of girls, like that of the boys should be pretty evenly divided between industrial and intellectual instruction"[20].

As well as these curriculur differences, girls tended to have less schooling than boys. There was a disproportion of girls who attended school and an inferior provision for them. For all children at this time schooling tended to be a sporadic experience[21]. There was no compulsion for them to attend school and not all districts had a school, or the facilities were inadequate for the population. Parents could easily withdraw their children to help with the harvest, work in the factories or mines or for some other sort of employment, or to look after other children at home[22]. Compulsory schooling could not be introduced until child labour had been controlled[23]. Even after the 1870 Education Act the average attendance was only sixty-eight per cent, rising to eighty-two per cent in 1900[24]. For girls however the situation was worse. Schools generally had fewer places for girls than for boys and added to this (and probably contributory to it), was the "general belief that education is less desirable for girls than for boys"[25].

Thus the early provison of education for working class girls and boys was class and sex specific. Contrary to Delamont's claim that working class education "was hardly differentiated by sex"[26], it is evident that the early state provision of education contained significant curricula differences determined by sex. The question here is how far these influenced the provision and content of science education?

Some historians of science education have argued that science was established in the education of the working classes for reasons of social control. Science education for the masses was perceived differently from science education for the higher orders in relation to a "mentality theory" of the nineteenth century. According to this the lower classes were believed to be of banausic mentality - simple and concrete thought - whilst the higher classes, developed from banausic mentality in childhood to gnostic mentality in adulthood, and were thus able to deal with abstract and complex thought. Science education for the masses, in this view, was perceived as a means of reinforcing the social order by stressing the laws of nature rather than scientific method and posing these as a new source of moral authority[27]. The purpose is not to discuss this here except insofar as it may throw light on the development of science education for girls. Could it be said to be a means of social control? Was it offering a particular moral code to its recipients?

Science education before 1862.

Until the 1850s science, with few notable exceptions, did not have a specific place in the curriculum. Rather it found its way into the education of elementary school children most frequently via the medium of "object lessons" and through the contents of the secular school readers which came initially from Ireland[28]. The diffusion of scientific knowledge was never the principal aim of such lessons, nor generally was science recognised as a "distinct mode of understanding"[29]. Rather the objectives in mind were to develop powers of observation and of reasoning, to extend language skills and to impart a knowledge of common things and to duly revere God's work[30].

There were two notable exceptions, during this period, to this prevailing mode of instruction. These were in the work of Richard Dawes, later the Dean of Hereford, and that of John Stevens Henslow, Professor of Botany at Cambridge University. Both men established village schools, the former at Kings Somborne, Hampshire, and the latter at Hitcham in Suffolk, where they introduced and developed science teaching as a distinct part of the curriculum[31]. Their work, however, was substantially different both in the science they taught and their method of teaching.

The study of the "science of common things" was Dawes' approach to natural science for the pupils in his school, most of whom were children of agricultural labourers. Governing his educational philosophy was the belief that by relating instruction to a culture which was familiar to the children, opportunities were provided for the "use of reason and speculation by drawing upon observations which pertained to everyday life"[32]. Much of the science taught was thus applied science relating the lessons to what would be familiar to the children. Whilst in no sense providing industrial training[33], it was designed to meet the educational end whereby all were prepared for "those duties and situations in life they are called on to fulfil"[34].

Henslow, by contrast aimed to train the "powers of observation and rational thought and (to improve) the intellectual and moral status of his pupils"[35]. His goal was education, not instruction, the latter in his view being useful for imparting information, but having no lasting influence upon the mind[36]. At his school in Hitcham he introduced a course of "systematic botany", chosen because "it provided for its practitioners a thorough training in close observation; but more than this it required them to understand those general principles which governed the classification of plants and which reproduced the general inductive laws of science"[37]. The classes were so popular that Henslow had to limit the number of volunteers to forty two[38].

Given these differences between the schemes of Dawes and Henslow, it is interesting that it was the science scheme of Dawes which was officially recognised long before that of Henslow and was to some extent held up as the model for the elementary schools[39]. By the 1850s the "science of common things" was being taught at least in name in some schools[40] whereas Henslow's systematic botany - suited more perhaps to those of "gnostic" mentality - completely bypassed the elementary school system finding its champions in the public and endowed schools[41].

This preference for the "science of common things" would appear to lend support to the "social control" explanation for the establishment of science education[42]. In Dawes' educational aim to prepare children "for those duties and situations in life they are called to fulfil" there are indications not only of how such an education might be class specific, but also sex specific.

In the section on "Mechanics and Natural Philosophy" in Dawes' influential book, "Suggestive Hints towards Improved Secular Instruction", the reference to boys suggests the audience for his lessons. This is substantiated by the account of Henry Moseley - an advocate of Dawes' work - of the science classes at the King Somborne village school[43]. From this it is learnt that "among the most interesting features of the girls school is the needlework" and also that "the morning's work in an elementary school differs from the boys in this, that it includes the instruction of the girls as well as the boys. In the afternoon the girls are occupied by sewing". Moseley went on to suggest that because of this arrangement there should be two sets of reading books, one for the morning and one which "prescribed an afternoon's lessons as well as one for the morning" which would be essentially different in spirit and character from those of the morning". The aim of such a book would be specifically industrial education, beginning with a book based on the "science of common things" followed with one "treating in an elementary way of handicrafts, horticulture and rural economy" and a third including the "processes of manufacturing art, agricultural chemistry and the higher principles of mechanism and mechanics". The girls meanwhile would have an afternoon book which could be learnt at home and "in which they may be examined as they sit at work". Such a book would "treat of cottage economy, of service, of cookery etc.". Whilst such subjects for girls may have had the potential for a scientific education and were included in the "Suggestive Hints", neither did they embrace the broad sweep of subjects which Moseley implied were taught to boys, nor could they have been taught experimentally if intended to be read at home.

Whilst there is little evidence that object lessons or reading books were directed specifically to children of either sex, the fact that Dawes' scheme of science education was widely adopted - if in name rather than any strict adherance to his method - is significant for the consideration of sex differentiation of the early science curriculum. It is suggested here that embodied in the form of science education taken up as the model for elementary schools was a concept of appropriate subjects for girls and boys related to their expected future occupations. As such, for girls the emphasis was upon matters relating to food, hygiene and household upkeep. This notion of appropriate subjects survived the decline in science teaching which occurred from the mid 1850s[45] and re-appeared with its reintroduction into the curriculum in the 1870s.

Science education after 1862

Science was not formally recognised in the school curriculum until the new Education Code of 1871. From this time object teaching became a standard subject and natural philosophy and natural science were included in this list of subjects which could earn grant as "specific subjects". This inclusion of specific subjects in science in the list of approved subjects followed pressure from the scientific profession. In 1870 a deputation from the B.A.A.S. led by their president for that year T.H. Huxley, presented to the Education Minister, Forster, their demand for the inclusion of elementary natural sciences in the Revised Code[46]. The interest and concern of the scientific profession was with the advancement of science and with the need for scientific talent to maintain and enhance their emerging profession[47]. Their principal desire in establishing elementary science education was to forge a link between elementary and secondary education so "that the youth of the country may be induced to take advantage of the more advanced schools"[48]. The Devonshire Commission, reporting on the state of scientific instruction and the advancement of science in 1872 underlined this view, not only recommending that more encouragement be given to science than had been given in the Code of 1871, but also that "Her Majesty's Inspectors should be directed to satisfy themselves that such elementary lessons are given as would prepare these children for the more advanced instruction which will follow"[49].

Investigating how science did develop as a part of the elementary school curriculum shows how little immediate impact the campaigns of the science lobby made upon the curriculum[50]. It is argued here that the addition of science was a piecemeal process, proceeding along pragmatic lines suited to perceived social needs and not in conflict with the expressed moral and utilitarian aims of elementary education. As discussed above, the Victorian concern with social stability along with the rigid class conceptions of society meant that the enhancement of social mobility was not an aim of the elementary school. Rather the goal was a deferential belief on the part of the child in its pre-ordained station in life. Such a goal both led to the extension of education to the working class but also to severe limitations of the extent of that education[51]. Science could be interpreted as quite contrary to such a conception of education especially with its delicate relationship to religion and the time it took away from that available for reading, writing, arithmetic and needlework. One parent made clear the possible opposition that could be encountered in attempts to widen the curriculum;

> "Sir, we were informed that our poor children were to be taught reading, writing and arithmetic only. Now this schoolmaster teaches them the contents of their own insides and thus adds to the rudeness which is innate in the lower orders. If the Author of the Universe had meant us to know what our livers are like he would not have hidden them away in security."[52]

As Selleck discusses, the introduction of specific subjects into the curriculum was done in such a way as to leave the pre-eminence of the three "R's" and needlework for girls, quite unchallenged. The specific subjects were second class subjects in the curriculum, earning less than the three "R's", being entirely voluntary and being limited to the upper standards[53]. Thus it should be clear that the Revised Code of 1871 did little to encourage science teaching generally. Opportunities for science in elementary education only began to open up when its relevance to social needs was recognised. This began to occur in the mid 1880s when, following a severe depression in trade and a sudden development in foreign competition the government instituted an inquiry into technical instruction[54], which was followed in 1889 by the Technical Instruction Act. A shift in educational philosophy away from concerns with the social order to new concerns of the nation and of industry[55] gave added legitimation to the inclusion of science in the curriculum. It could claim superiority as an educational subject because it could answer a national problem and meet the demands of being an intellectual discipline[56].

For the consideration of the scientific education of girls, this late interest in science is significant because when science did begin to be more widely accepted in the elementary schools in response to perceived social needs, little was altered in the conception of what constituted a science education for girls beyond its greater encouragement and advocacy of new methods. Such a conception of science education found a place in the curriculum for girls at a comparatively early stage because it met a social need which future women were to fulfil[57]. When pressures were being mounted for the inclusion of science in the elementary schools in the late 1860s and early 1870s the assumption was made that domestic economy was the subject that girls should learn. From this time at least domestic economy was considered by some as belonging to the sciences. The Rev. Canon Norris giving evidence to the Devonshire Commission suggested that cooking fell under the heading of elementary science. Asked whether any instruction in science was attempted at Mr. Armistead's school in Sandbach he replied positively for the girls' school, but not for the boys. On questioning the girls he found "that they understood why fires smoked and how fuel might be economised to some slight extent. Lessons had been given them on those subjects and something about the opening of windows and the need of fresh air for health"[58]. Similarly believing that the science subject taught should vary with the "locality and with the class and character of the school", the Rev. F. Watkins, in his evidence to the same Commission made it clear how science education should differ between girls and boys, and between rural and urban schools;

> "I should say that in all schools there should be some of the elements of physiology, and I should say that in all schools there should be some of the elements of geography....and in the town schools I should like to see something of the elements of chemical science. In country schools, I think in agricultural districts, something might be done in botany and agriculture, and in all girls schools something of domestic economy."[59]

This assumption was also made by the Liverpool, the London and the Birmingham School Boards[60]. Using peripetatic science demonstrations, mechanics for boys and domestic economy for girls were chosen as the subjects most suitable for the purpose of imparting a systematic instruction in science. Domestic economy was made a specific subject in 1875 and in 1876 the rule was made compelling girls to make domestic economy their first choice of specific subjects[61]. This rule accounted for the fact that by 1881 domestic economy far superseded any other subject presented as a specific science subject:

Table 1. Numbers presented for examination in specific subjects, nationally, 1881.[62]

Specific subject	No. of candidates
Mechanics	2,109
Animal Physiology	24,725
Physical Geography	34,288
Botany	1,853
Domestic Economy	50,797

The corresponding figures for the London School Board, in numbers of departments in which the specific science subjects were taken up were:

Table 2. The number of departments of the London School Board presenting candidates for examination in specific subjects, 1881.[63]

Specific subject	No. of departments
Mechanics	4
Animal Physiology	123
Physical Geography	112
Botany	9
Domestic Economy	172

Close in numbers to domestic economy at this time were the subjects of animal physiology and physical geography. The latter subject had a traditional hold on the curriculum having been one of the first specific subjects listed when they were introduced in 1867. Animal physiology found its place and popularity partly owing to the contemporary concerns for public health. It was felt to be an important subject in the education of children for their health of body and mind[64]. That it required little apparatus was also a factor in its popularity[65]. Its popularity remained unshaken until the late 1880s, when the demand for technical instruction promoted the teaching of mechanics to boys[66]. However, there is evidence that girls would rarely take either animal physiology or physical geography because of the compulsion to take domestic economy as a first subject. This is clearly shown in table three.

Table 3. Number of children presented for examination in specific subjects, 1883.[67]

SUBJECT	PRESENTED Boys	PRESENTED Girls	PASSED Boys	PASSED Girls	% OF PASSES Boys	% OF PASSES Girls
English Lit.	2,062	1,952	1,858	1,422	90	72
Maths.	44	-	40	-	90	-
Latin	3	-	3	-	100	-
French	9	-	5	-	55	-
Mechanics	10	-	9	-	90	-
Animal Phys.	2,037	5	1,740	5	85	100
Phys. Geog.	1,567	22	1,019	21	65	95
Botany	373	11	330	11	88	100
*Dom. Econ.	-	2,302	-	1,565	-	67
	-	2,302	-	1,336	-	58
TOTALS	6,105	6,594	5,004	4,360	81	66

*In two parts and the girls are compelled to take both.

If a second subject was taken by girls it was most likely to be English Literature[68].

Of course it is questionable just how "scientific" these subjects were. Bremner notes that the popularity of animal physiology fell in the 1880s when Huxley and colleagues attempted to change it "from a means of health instruction" to "a scientific discipline".[69] There was a resistance to the study of the structure and functions of different organs when what was required was instruction in the laws of health.

The scientific nature of domestic economy is also not beyond question. By some it was undoubtedly seen as a way to get round the constraints of the various codes and to use it as the basis for a general science education - even if biased towards domestic concerns. The definition of the subject was "of such nature as to allow of the instruction being considerably expanded....in the direction of....elementary chemistry, physics and physiology"[70]. In Birmingham a similar wide interpretation was placed upon the subject so that "under the head of domestic economy as much elementary chemistry and physiology are taught as will enable an intelligent girl to comprehend the familiar facts of home life"[71]. Such lessons were evidently popular. W. Jerome Harrison cited incidences of girls "who cannot escape from tyrannical babies" begging leave "to bring their charges into the classroom", and of mothers being persuaded to change their washing day so that the demonstration lesson may not be missed.[72] They were also successful both educationally making "a perceptible increase in (the girls) intelligence"[73], and in effects judging by the case of the irate landlord who visited a school to "'know what they meant by teaching children that his houses were not fit to live in' the said houses being built back to back a practice the evils of which are pointed out in one of (the) domestic economy lessons".[74]

In spite of the scientific interpretations which could be made upon domestic economy, it is also clear that the subject had to embrace too much to offer any more than a superficial treatment of the subject matter.

A study of some of the textbooks in use shows a familiar pattern of dealing with the composition and value of food, its preparation, cooking apparatus, household management and hygiene; although a distinction was made between cookery and domestic economy lessons. The former, as in W.B. Tegetmeirs "Handbook of Household Management and Cookery"[75] compiled at the request of the School Board for London, or C. Buckton's "Cookery Scheme of the Leeds School Board"[76], were much more practically orientated, dealing largely with the preparation of food, with perhaps some reference to such things as the structure of yeast, and optional lectures on diet and nutrition[77]. However, the aim generally of such a course was to teach the girls "plain cooking, washing and cleaning, enough to prepare them for service, or to make them useful mothers at home".[78]

The subject matter of domestic economy tended to cover the same ground more theoretically, with greater emphasis on the processes of cooking, hygiene and basic elements of physiology, but of course the treatment of it would vary depending on the age of the pupils and the teacher. A course on the "science of home life"[79], for example, included a mixture of scientific explanation and practical application. In the third year course book the first two chapters dealt with the structure and functions of the human body and its various organs. Following this were nine chapters on food. Continuing from the first two books in which the composition and functions of food had been studied, this book dealt with the nutritional and diet aspects, principles of cooking, preparation and apparatus. The last six chapters dealt with health and hygiene. In his "Teachers Manual of Lessons on Domestic Economy", H. Major[80] pointed out just how far the subject should be dealt with scientifically. The manual was mainly for teachers teaching domestic economy as a class subject. In Standards I to III, lessons followed the government requirement in including the "principle substances used for food and clothing" in the form of object lessons[81]. It was at Standard IV that a "scientific handling of the subject of domestic economy" was approached because the subject "now trenches close upon <u>hygiene</u>, <u>human physiology</u>, <u>chemistry</u>, <u>sanitation</u> and <u>cookery</u>"[82]. However, Major stressed that the scientific information incorporated in the teachers manual was to aid the preparation of the teacher rather than being an intrinsic element of the course. Such a view was justified in terms akin to the "mentality theory" noted above;

> "the children can only understand the broadest principles of these sciences and should have their attention confined to those departments of them which are the most <u>practical</u>, and most calculated to be of use to them <u>in after life</u>".[83]

In Major's view this was regrettable, but some compensation was had by the fact that, "it is Domestic Economy as a 'class' subject, not as a 'science' or 'specific' subject that was under discussion"[84]. Similar proviso's were made for the lessons for Standard V and VII. Lessons on the "nutritive value and functions of food" implied "some elementary notions of mastication, deglutition and digestion, so far as children in Standard V can be made to intelligently comprehend these...."[85]. Again care was taken that in lessons on personal cleanliness, involving the physiology and functions of skin, "no greater demand shall be made on the intelligence of the children than girls of the age of Standard V"[86]. The final lessons, taking up "pure hygiene" for girls in Standard VII were to be treated in "a less scientific, and a more popular manner than for Science classes"[87]. As a class subject at least, the implication from Major is that domestic economy gave a very superficial treatment of anything approaching science. This was justified on the grounds of the mental capacity of the children but also, and as importantly, on the practical importance of the subject[88].

Even in domestic economy lessons in which the stated aim was to give a systematic instruction in science it would appear that in many schools the reality was far from the ideal. As the Rev. D.J. Stewart noted of the schools in Greenwich;

> "The practical nature of (the girls) compulsory subject requires for its successful preparation very careful oral lessons and many experimental illustrations, instead of which, in many instances little had apparently been done judging by the childrens papers, beyond getting up a book. Often the answers have consisted almost of entirely garbled passages from 'the book' which they had evidently tried to commit to memory."[89]

Clearly, although domestic economy had potential for offering an introduction to scientific principles to girls of about nine and older[90] and found support as both theoretical and practical instruction in order that it could fulfil "its proper value as a means of training"[91], the emphasis was upon imparting a useful education to "the girls, who will subsequently become the mothers of the future working classes of this country"[92]. In the elementary schools at least, domestic economy became the vehicle for a variety of subjects which dealt with the care and management of the home and family. At best it appeared to give a superficial introduction to aspects of physiology and chemistry, but from the 1880s owing to successive Education Codes which gave it and other domestic subjects priority, it may have been the most significant form of education in science for many girls.[93]

In spite of the demand that domestic economy should be the first subject a girl should take, there were other opportunities throughout her schooling for a girl to learn science. These too can be shown to be influenced by conceptions of appropriate subjects for girls compared to boys. Object teaching had persisted in a relatively unchanged form in spite of the setbacks of 1862. It was officially recognised once more in 1871. Such lessons were generally designed for the infant schools, aiming to develop "the perceptive powers and intelligence of the children"[94], but were also frequently taught in school departments for older girls and boys. In many of the schools of the London School Board "advanced object lessons, generally on natural history"[95] were taught and were seen as the vehicle for a more general and systematic education[96]. Elsewhere however there is evidence that object teaching suffered like the lessons in the 1850s, from formal and unsystematic treatment[97], unregulated by inspection, and through not being grant earning, lacked any standardisation[98]. As one critic observed, far from being a systematic introduction to science "these exercises are notoriously loose, desultory, incoherent and hardly deserve the name of mental training"[99]. The content of the lessons ranged over a variety of subjects from animals, plants, birds, to foodstuffs, metals, minerals and "common things" such as a candle, paper and soap[100]. By the end of the century the London School Board, at least, appeared to use the object lessons for a more systematic instruction. One textbook based on the scheme shows lessons on "common objects" dividing these into porous substances, soluble substances, adhesive substances and metals, lessons from plants and lessons from animals[101]. Although the pupils for such lessons were not specified, some notion of appropriate subjects is intimated in the preface which suggested that for girls' schools and smaller schools, the "lessons dealing with Animal and Plant Life alone would make an interesting and useful course"[102].

In the higher standards the class and specific subject were opening up possibilities for science education, but as noted above these were slow to become generally taught and for girls the opportunities were very circumscribed. Elementary science was made a class subject in 1882 aiming to improve upon object teaching and to give a systematic course which would lead to the study of a specific branch of science[103]. Although slow to become established in elementary schools, like object lessons it would appear that it was intended for pupils of both sexes.

However, there are several indications which suggest that sex played a fairly important part in deciding how it was to be taught.

By the end of the century a tendency was perceived in elementary schools "towards the general teaching of Elementary Science (for girls) on a biological instead of a physical basis"[104]. This tendency may well have been instituted in 1882 when the London Board devised a scheme for teaching natural science to Standards I to VII. From Standard V alternatives were given based either on the biological sciences or on the physical sciences, although at this time no mention was made of either course being intended for boys or girls. Significantly for girls perhaps, teachers were not obliged to teach the set scheme and were informed that they had "full liberty to vary it according to their tastes and requirements"[105].

At the very end of the century the London School Board were advocating experimental science instruction for girls as well as boys[107]. Although in this instance the content of the course, as described by W.H. Grieve, science demonstrator, was similar for all pupils, the aims of the course were quite different for girls as one example will show;

> "The course proceeds to deal with the general effects of heat upon matter. The girl here obtains, from very simple experiments, a correct idea of the principles of ventilation, the construction and use of clinical and household thermometers; and the boy can learn at what period of the frost his father's water-pipe bursts.
>
> The girls then study the difference between conduction, convection and radiation of heat. From a simple experiment, which they themselves perform, they can tell you why a cotton fabric is to be preferred to a woollen one in the summer, why the water in the boiler rises to the cistern in the bathroom; or whether water boils more quickly in a kettle covered with soot than in one new and polished. The boy can explain why ice is packed in flannel or felt in summer and why it is necessary, when descending mines, that the safety lamp should be surrounded by a gauze of close mesh."[108]

As a further indication that the elementary science curriculum was sexually differentiated, the London Board reported that by the 1880s domestic economy, which was taught outside of the schools in specially equipped centres, was correlated with "the Object Lessons

Table 4. Scheme for the teaching of natural science in the schools of the London Board, 1882.[106]

Standard I.	Standard II.	Standard III.	Standard IV.	Standard V.	Standard VI.	Standard VII.
Extension of the Object Lessons in the Infant School, with simple illustrative experiments.	Comparison of different plants or animals. Ordinary phenomena of the earth and atmosphere. Substances of domestic use.	Simple principles of classification of plants and animals. Further phenomena of the earth and atmosphere. Substances used in the Arts and Manufactures.	More complete classification of plants and animals, with typical examples. The three forms of matter familiarly illustrated.	a) Animal and plant life, with the most useful products; or, b) More definite notions of matter and force illustrated by simple machinery or apparatus.	a) Animal and plant life, with special reference to the laws of health; or, b) The commonest elements and their compounds. The mechanical powers.	a) Distribution of plants and animals, and the races of mankind; or, b) Light, heat, and electricity, and their applications.

and other forms of Elementary Science in Girls and Mixed schools"[109]. That this was common practice may be tentatively concluded because of the inclusion of domestic economy in the alternative schemes of elementary science possible after 1890[110].

Thus it can be seen how with the encouragement and priority given to domestic economy and the assumptions which underlay the teaching of elementary science and possibly the object lessons, the conception of what constituted science education for girls was markedly different from that of boys. Contrary to current justifications for differentiation in science education on the grounds of sex specific abilities or aptitudes for certain branches of science, the nineteenth century differentiation of the science curriculum was based upon preconceived notions of future occupations[111].

By the end of the century changes were beginning to take place in the elementary schools displacing the formal study of science to the higher standards and emphasising object lessons intended to "train observation, to promote delight in nature and to lay foundations for a more formal study of science"[112]. This trend received added encouragement following the establishment of the Board of Education in 1899 and the gradual abolition of elementary, class and specific subjects. In their place was favoured a "connected and coherent curriculum" and successive education codes stipulated courses of observation lessons and nature study rather than courses on specific branches of science[113].

For younger pupils corresponding to today's primary school children, it would appear that by the beginning of the twentieth century the ascendance of nature study was, at least superficially, erasing obvious sex differences in the pupils' initial introduction to science[114]. Domestic economy remained in the curriculum for girls, but, as will be discussed in chapter 5, it was increasingly justified as practical and manual education rather than science education.

Turning now to look briefly at the developments in post elementary education it will be seen that opportunities for the formal study of science were opening up towards the end of the nineteenth century, but these were not without reference to a conception of appropriate subjects for women.

Science education for girls in post elementary education.

The elementary schools were intended to give an elementary education to children of the working classes. After the 1870 Education Act there was a legal commitment on such schools to provide an education for all children up to the school leaving age which was not fixed, but could be as early as ten[115]. By the 1880s certain developments had taken place within the elementary school system which offered the possibility for some children to obtain a more advanced education and even find their way to the new universities and technical institutions developing at this time[116].

These developments were made possible by the grants available from the Department of Science and Art (D.S.A.) in South Kensington and the trend from the late 1870s for more children to stay at school beyond the age of twelve.

The Department of Science and Art had been established in 1853 to encourage the scientific and artistic education of the "industrial classes". Movements in this direction were further encouraged by the Report of the Select Committee on Scientific Instruction in 1868 which, in the name of industrial progress, felt that "technical instruction" to all from workman to manager was desirable[117]. Through the medium of the D.S.A. a network of science classes was established throughout the country in Mechanics Institutes, Lyceums and some schools[118]. From the 1880s grants from the D.S.A. were used by some school boards to finance more advanced work in the elementary schools. This first occurred in those schools in which a significant number of children stayed on beyond the age of twelve, but during the 1880s and 1890s some school boards centralised these higher grades "bringing together in a separate school the older and more advanced pupils from a number of schools whose parents wished them to stay on to thirteen, fourteen or even fifteen and older. Such schools were known as the higher grade schools"[119].

A further development was made possible by the institution of substantial grants in 1872 by the D.S.A. for a three year course of science and related subjects[120]. Schools which made use of this grant were known as "organised science schools" and these could be found in either one or two senior classes of the board schools or later the higher grade schools[121]. For schools which did not wish to adopt the science curriculum stipulated by the D.S.A., grants were available for individual subjects[122].

The higher grade schools offered for children of unskilled or semi-skilled parents the opportunity for a more advanced education of a more practical nature, but comparable with the type of education to be found in what were termed the "middle-class schools" - the grammar and commercial schools. Furthermore owing to their attachment to School Boards and their receipt of grants from the D.S.A., education in the higher grade schools was much cheaper than that of the independent schools. By the mid 1880s grammar schools were losing their traditional pupils to these schools[123].

Given the co-educational nature of the elementary school system it is to be supposed that the higher grade schools and organised science schools offered for girls as well as boys opportunities for a more advanced and systematic instruction in science. Lack of information makes conclusions as to the extent and nature of science teaching for girls in this period impossible. However, evidence from various sources suggests that some opportunities, if limited, were available.

From the statistical returns of the D.S.A. it is evident that by the mid-1860s some science schools (denoting any schools or part of a school which earned D.S.A. grant)[124] were catering for girls or women[125]. However, the number benefitting from these was small. Between 1866 and 1872 only 143 had been entered for a science examination of the D.S.A. compared with an overall total of 38,015[126]. Interestingly, however, the subjects taken were far from those related to domestic concerns, including geometry, machine drawing and construction, magnetism and electricity, inorganic chemistry and mineralogy. Some women were particularly successful; Jane Goffin a teacher, aged thirty-three, won the silver Queens Medal in 1867 for her achievement in the acoustics, light and heat examination; and Elizabeth Hollis, the sixteen year old daughter of a builder, won the same medal for her attainment in magnetism and electricity[127]. The following year Sara J. Doherty, a twenty-four year old teacher won the gold medal for acoustics, light and heat, and a monitress, Anne Swiney aged eighteen, the silver medal for magnetism and electricity[128]. It is possible to speculate that these science classes offered working-class women a rare opportunity to obtain an education in science and an education radically different from that usually on offer in adult education establishments for women[129].

Information regarding the higher grade schools is only slightly better. Until 1882 only one organised science school existed as a separate entity - Nottingham High Pavement[130], but by 1893 there were seventy such day schools and nine evening schools[131]. Initially the higher grade schools may have had separately organised science classes which earned the D.S.A. grant before becoming an organised science school. In London, for example, four organised science schools were established to accommodate the growing number of pupils presented for D.S.A. examinations in science[132]. From the D.S.A. annual returns it appears that the girls' sections of the schools were slower to take advantage of the D.S.A. grant than were the boys. The first entry for a girls' higher grade school was in 1887 with the Leeds Central Higher Grade School for girls, followed in 1889 by the Nottingham Higher Grade Girls' School[133]. Nottingham is interesting because in 1894 whilst three organised science schools were listed, all of which were higher grade schools, the girls' sections of the schools were not listed as organised science schools[134]. The assumption is that whereas the boys' section of a school became an organised science school, the girls' section took selected science classes only.

From the mid 1880s there is a little more information on these schools and their curricula. In 1883 in Manchester science was taught in the higher grade board schools under the direction of the D.S.A. In four of these, science lessons formed a part of the ordinary day school work and in two others "some of the more advanced boys and girls (came) for one hour in the evening for similar instruction"[135]. The subjects taught were maths; physiology; inorganic chemistry; organic chemistry; sound, light and heat; magnetism and electricity; physiography and theoretical mechanics. There is no indication that girls followed a different set of subjects from the boys. In the specimen curricula given as part of the report of the Bryce Commission the girls' department of the Leeds Central Higher Grade Board School, which included an organised science school, was shown to spend up to seven hours a week on physical science and between two and three and a half hours a week on geometry or botany. This contrasted with the girls' department of the Sheffield Central Higher Board School which was not an organised science school. Here up to five hours a week were spent on hygiene and physiology[136].

By the end of the century, however, there is evidence that different sciences were increasingly associated with either boys or girls. W.H. Grieve noted that in the Blackheath Road School of Science in Greenwich, of the 25,957 hourly attendances made in 1899, 2,469 of these were by girls studying hygiene and physiology. Of the candidates for scholarships of the Board, the boys selected physiology, elementary science, chemistry and mechanics, whereas the girls "preferred to take domestic economy in 54 cases, physiology in 17 cases and botany in 3 for their science subjects"[137].

Even in schools such as the Leeds Higher Grade School, which appeared to offer a substantial science education to girls, the science may well have been taught to complement instruction in domestic subjects[138]. Also, it should be noted that the number of hours devoted to science in this school was less than that for the boys[139].

From this limited information it would appear that the science classes of the D.S.A., whether for specific subjects or in an organised science school, offered some girls further opportunities for the study of science. Whether this was by intention and for what motives, or whether it was simply because grant was available, is not clear. Evidently more information is required on this point and upon the subsequent careers of the girls in these schools. There are formidable methodological problems here relating primarily to the lack of documentary evidence[140] and the problem of tracing women's careers, particularly if they were not in any way famous or exceptional. An analysis of women science students at the new universities from the 1880s would perhaps throw some light on the extent to which the higher grade schools offered girls an entry to advanced studies in science, but such an analysis would almost certainly be hampered by similar problems[141].

In spite of these problems it is clear that the higher grade schools for girls which did offer a systematic instruction in science were an exceptional form of education for a minority of girls who would have stayed at school beyond the age of twelve. Furthermore, there is strong evidence that the science curriculum was increasingly circumscribed and determined by social pressures to relate girls' education to domestic concerns. By the end of the century there were definite pressures to institute a specific curriculum in the girls' schools[142]. After 1895, "the rigid rules and (the) theoretical curriculum together with a system of payment by results (which had) led to a stale and unimaginative teaching"[143] were relaxed by the replacement of the payment by results system with capitation grants and by the widening of the curriculum to include literary subjects[144]. In the revised regulations of 1895 "special provision was made for the scientific instruction of girls"[145]. Substantial differences were introduced between the male course and the female course. The latter, in the elementary course excluded physics and mechanics included in the male course, but included elementary physiology or botany, physiography or hygiene. In the advanced course male pupils were allowed to select one course from advanced physics or chemistry, advanced mechanics or advanced biology - all of which had some compulsory subjects such as mathematics or inorganic chemistry. The advanced course for females was simply a repeat of the elementary course - mathematics, elementary or advanced geometry, theoretical and practical physiology or botany and physiography[146]. After the 1902 Education Act, the higher grade schools were transformed into the municipal secondary schools. From this time the development of the curriculum was influenced by two forces. The first was that of successive Secondary Regulations which laid down a core curriculum corresponding to contemporary notions of a balanced education. The second was the influences of the teachers and headmistresses in these new schools, many of whom had come from the girls' high schools and brought with them the ideals and traditions of these schools[147].

Thus whilst there may have been real opportunities for girls to study science in a more systematic way towards the end of the nineteenth century, in the higher forms of elementary education, preconceived notions of women's role in society tended to define the nature and extent of that education. Similar trends were apparent in the women's training colleges, which will now be discussed briefly.

Science education in the women's teacher training colleges.

The women's training colleges offered the greatest opportunities for working class girls to continue their education[148]. However, the opportunity that existed was limited by the objectives of the colleges - to train elementary teachers. From the earliest days of the colleges in the 1840s natural history and domestic economy had generally been on the women's curriculum and were advocated as strongly as were the physical sciences in the men's colleges[149]. In 1862 , owing to the effects of the Revised Code which struck "all but religious knowledge, history, geography, arithmetic and two books of Euclid"[150] off the curriculum, some principals of training colleges "so convinced of the value of scientific knowledge prepared their students for the May exams of the D.S.A. and permitted them to attend those exams thus qualifying themselves to earn grant under the Department"[151]. At this time physical geography appeared to be the subject generally taken by women compared with a wide selection of subjects taken by men[152].

This sytem of taking the D.S.A. exams continued until the end of the century, the numbers of students being so great that in 1878 the training colleges were no longer included in the D.S.A. annual returns but were entered separately in the Report of the Committee of Council on Education. Also at this time the training colleges made a break with the D.S.A. by holding their examinations at Christmas and not in May. Not all the subjects were examined by the D.S.A. There was a compulsory list of subjects which differed for men and women in that where men took algebra, mensuration and Euclid, women took needlework and domestic economy[153]. In the science subjects which were under the D.S.A. the regulations for women were different in that they were allowed to take only one subject per year compared with the two allowed for men[154]. In an appendix to the regulations in 1881 this was modified to either one language or one science for female students, who could take neither in the second year unless they had passed history or geography with credit in the first year[155]. This discouragement in the pursuit of science for women appeared again in the appendix for 1890 which stressed that,

> "If a student takes up a science subject in her first year, and fails to pass in it, she must, should she present herself in science at all at the end of the

> second year, take up the subject in which she failed, but she may drop science altogether in favour of another optional subject".[156]

However, 1891 saw an expansion of opportunities for women. The regulations removed some obstacles to choosing science subjects and no difference was made between men and women[157]. By this time a few women students had broadened out their choice of subjects from animal physiology, physiography, agriculture and botany, which had until then been the only subjects taken by them. In 1887 the first women students entered the examination on magnetism and electricity, and in 1891 the examination on sound, light and heat was chosen by twenty-one women. In fact only five colleges - Edge Hill, Homerton, Stockwell, Whitelands and Tottenham - had any tradition of entering women students for more than a narrow range of by now predictable subjects. In these colleges magnetism and electricity, sound, light and heat, chemistry and theoretical mechanics evidently formed part of the instruction in science[158]. These students represented a very small number of the total[159] and the fact that they took these subjects implies a specific interest on the part of a member of staff and access to adequate equipment. This is evident from the 1895 regulations which laid down that,

> "no student may take any science subject unless a special course of instruction is provided in the time-table of her college and all apparatus for practical instruction in that subject is supplied"[160].

Given the limited objectives of the training for teachers, it was not to be expected that many women's colleges exploited the possibilities for a more advanced or wide-ranging science education. A Mr. H.A. Reatchlous stated to a conference on education in 1884 the rationale for science education at the training colleges,

> "it is plain....at the outset that the study of science in training colleges must bear a relation to that of the other subjects of the syllabus similar to that which the teaching of science in primary schools bears to that of other subjects of the curriculum. Further, the considerations which determine the relative time to be given to science in a training college determine also the character of the instruction itself. If a man (sic) is to study many subjects it follows that he must be content with an elementary acquaintance with them and his

knowledge can only be complete within well defined and restricted limits".[161]

In 1897 distinct option choices were again detailed for men and for women, so increasing the constraints applied in 1895 when physiography became the compulsory first year science option for all students[162]. The major difference in the two option lists was that the list for women included physiology, botany and hygiene, subjects which were not included in the list for men. Although mathematics did not appear in the women's list, this regulation gave a greater choice to women, although in practice botany and hygiene were by far more popular than any other of the subjects. From what has been noted above it could be suggested that such popularity owed more to compulsion and/or lack of teachers and equipment than free choice.

Thus, although the training colleges did enable some women to study subjects such as magnetism and electricity or chemistry, those who did so were in a minority. The sciences most studied by women were the familiar ones of physiology, botany and physiography with the addition of agriculture from about 1886, superseded in its turn by hygiene in 1895. Needlework and domestic economy were of course compulsory subjects throughout this period as hygiene was later. In many ways the limitations of the training schools are unremarkable given that students were trained with the single objective of returning to the elementary schools. Scientific knowledge for women teachers was required to complement the instruction in object lessons, nature study and domestic economy. Nowhere was there articulated a demand for the scientific education of women college students beyond these objectives.

Science education for working-class girls.

Science education of a sort was available in some elementary schools from the 1850s in the form of the "science of common things" and object lessons. However, for girls in the elementary schools emphasis was always laid upon preparation for domestic life. In this way needlework and later cookery, domestic economy and hygiene tended to feature in the curriculum for girls and to determine the development of their science education. This was the case throughout the nineteenth century in spite of the extension and diversification of educational provision. Domestic concerns also tended to narrow the curriculum designed for women training college students.

Descriptive detail has been dealt with at some length because so little is known of these early developments in science education for girls. What it does show is that science for girls has not always been equated with botany and the biological sciences although with the later specialisation within the science curriculum it is obvious that biology was considered the most appropriate science for some girls, given its domestic implications. The chapter also shows that it was only within clearly defined limits that science education was considered important for girls. With the emphasis on the need to apply science evident towards the end of the century, and given the ideology of separate spheres for men and women, it is clear that for girls within the elementary education system science education beyond that which would improve their work as domestic servants, mothers and housewives was not considered as important as it was for boys. The mechanical and physical sciences - the sciences which were required by industry - were therefore absent from the curriculum for girls.

Parallel developments in education for middle class girls (to be discussed below) appeared to have little influence on the development of education for working-class girls except in the later development of the higher grade schools into municipal secondary schools after the 1902 Education Act.

In many ways this chapter could be regarded as mapping out a terrain for future investigation rather than providing firm conclusions. More information is needed particularly on the treatment of science for girls in the higher grade and organised science schools and the possibilities open to these girls for further education in science at the new universities and technical institutions. Similarly more information on the treatment of science in training colleges for women and men would not only be of interest in itself, but perhaps throw more light on science education in the elementary schools themselves.

References

1. This strict division of society into working class and middle class is not without its problems. Class boundaries are not static and classes are not homogeneous groups. Towards the end of the nineteenth century children of artisans could be found at the same educational institutions as those of professional parents, whilst some middle class parents took advantage of the cheaper education offered in the board schools, originally intended for children of the working classes. However, the distinction has to be made as the formal provision of education in the nineteenth century was in its intentions clearly class specific.
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7. See for example: Selleck, R.W., The New Education - The English Background 1870-1914, Pitman, 1968, chapter 1; McCann, P. (ed.), Popular education and socialisation in the 19th century, Methuen, 1977; Johnson, R., "Educational policy and social control in early Victorian England", Past and Present 49, pp.96-119.
8. Johnson op.cit., p.100.
9. ibid., p.119.
10. Although it should be noted that amongst the bourgeoisie there were sections of opinion that the working classes should not be educated for fear that they would rise above their station in life. See Shapin, S. and Barnes, S.B., "Science, Nature and Control: Interpreting Mechanics' Institutes", Social Studies of Science, Vol.7, 1977, pp.31-74.
11. Johnson, op.cit., p.107.
12. ibid.
13. Davin, A., "'Mind that you do as you are told' : reading books for Board School girls", Feminist Review, vol.3, 1979, pp.89-98, (p.90).
14. "Report by H.M.I. the Rev. Muirhead Mitchell, M.A., on schools inspected in the North Midland District, comprising the counties of Chester, Salop and Stafford for 1847", MCCE, 1847-8, p.131.

15. "General Report for the year 1863 by H.M.I. the Rev. R. Temple, M.A., on the Church of England Schools inspected by him in Yorkshire and Cheshire", MCCE, 1863-4, p.149.
16. "Report on Schools in the Northern District by the Rev. F. Watkins," MCCE, 1844, p.251.
17. Adamson op. cit., p.129.
18. "Report on Schools of Industry by S. Tremenheere Esq.", MCCE, 1842-43, p.139.
19. "Report on the State of Elementary Education in the Mining Districts of Durham and Northumberland by the Rev. J. Allen," MCCE, 1840-41, p.134.
20. "Report of the School of Industry at Norwood by Seymour Tremenheere", MCCE, 1842-43, p.168.
21. In 1841 the Rev. Baptist Noel reported that in two national schools in Lancashire "reported to contain 220 boys and 104 girls, I found 170 boys and 76 girls: in another, where the reported number of children was 190, I found 67: another, said to have 95 mustered on the day of my visit 50; and in several other schools I found the actual numbers inferior to the reported numbers". (MCCE, 1840-41, p.159).
22. Johnson op. cit., pp.108-110.
23. Heward, C.M. and Woods, M.E. "The Childrens Employment Commission, Reports 1-6, 1862-1867, as a source for the history of education," History of Education Society Bulletin, no.27, Spring 1981, pp.36-45.
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26. Delamont, S. "The Domestic Ideology and Women's Education", in Delamont, S. and Duffin, L., The nineteenth century woman - her cultural and physical world, Croom Helm, 1978, pp.164-187.
27. See, Shapin, S. and Barnes, S.B., "Head and hand : rhetorical resources in British pedagogical writing, 1770-1850", Oxford Review of Education, vol.2, 1976, pp.231-254; Shapin and Barnes, 1977, op.cit.; Millar, R.H., "Curriculum rhetoric and social control : a perspective on recent science curriculum developments", European Journal of Science Education, vol.3, no.3, 1981, pp.271-284; Hodson, D. and Prophet, R.B., "The influence of phrenological theory on the science curriculum in Victorian England", European Journal of Science Education, Vol.5, no.3, July-Sept. 1983, pp.263-274.

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29. Layton, 1973, op. cit. p.28.
30. For this view of object lessons, see; Noel, B.W., "Lessons on objects as given to children between the ages of six and eight in a Pestalozzian school at Cheam, Surrey", Appendix to the MCCE, 1840-41, pp.169-170.
31. Layton 1973 op. cit., see chapters 3 and 4; Russell-Gebbett, J., Henslow of Hitcham, Terence Dalton, Suffolk, 1977.
32. Layton 1973 op.cit., p.53.
33. ibid., p.48.
34. quoted in, Moseley, H., "Report for the year 1847", MCCE, 1847-8, I, p.27.
35. Layton 1973 op.cit., p.60.
36. ibid., p.58.
37. ibid., p.62.
38. Russell-Gebbett op.cit., p.45.
39. Layton 1973 op.cit., p.36; see also Moseley, op.cit., pp.9-35.
40. Layton 1973 op.cit., p.124.
41. ibid., p.37; Russell-Gebbett op.cit.; see chapter 4.
42. In this respect see Hodson and Prophet op.cit., pp.16-18, where they argue that "Dawes and his contemporaries in elementary science education were engaged in the articulation and development of an ideological education for the poor" (p.16).
43. Moseley op.cit., pp.16-27.
44. Russell-Gebbett op.cit., chapter 4; Layton 1973 op.cit., p.67.
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46. Layton, D., "The Schooling of Science in England, 1854-1939", in MacLeod, R. and Collins, P., The Parliament of Science, Science Reviews, Northwood, 1981, pp.188-210, (p.199).
47. ibid.
48. ibid.
49. Royal Commission on Scientific Instruction and the Advancement of Science (CSIAS) 2nd Report, 1871-2, p.xix.
50. Indeed, by the turn of the century they were forced to conclude that "science has in no way taken its proper place in our system of elementary education", Layton 1981 op.cit., p.199.
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52. Quoted in Lowndes, G.A.N., The Silent Social Revolution, Oxford University Press, Oxford, 1970, p.19.

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56. ibid., p.121.

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88. This will be discussed more fully in chapter 5.
89. Stewart, op.cit., p.400.
90. See "Mr. Hernamens General Report for 1883, West Lambeth", MCCE 1883-4, p.313, the suggestion here is that girls from Standard V were taking domestic economy.
91. "Mr. Fussell's General Report for 1876, Finsbury District", RCCE 1876-77, p.485.
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the Committee of Council on Education calls were made to lower the required standard of attainment in arithmetic for girls owing to the time required for needlework and other subjects. This was the focus of much feminist concern about girls' education. See Becker, L., "On some maxims of political economy as applied to the employment of women and the education of girls". BAR 1871. p.201; Bremner, C., The Education of Girls and Women in Great Britain, Swan Sonnenschein & Co., 1897, pp.47-49; "Sewing for Girls", Journal of Education, Nov.1 1895 pp.618-620.

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122. Simon, op.cit., p.178.
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125. Science schools could also be held in the evening catering for adults and older children, hence the DSA statistics for female students could refer both to girls and women.
126. This figure may not be strictly accurate because we do not know the numbers of girls in mixed classes. Also the larger figure refers to the whole of Great Britain whereas the smaller number denotes female students in science schools in England only.
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128. DSA 16th Annual Report 1868-69, p.132.
129. As Purvis discusses, adult education for women was heavily dominated by the '3 Rs' and needlework. (See Purvis, J., "Working-Class Women and Adult Education in 19th Century Britain", History of Education, Vol.9 no.3, 1980, pp.193-212; "Inequality in the education of working-class women 1854-1900", History of Education, Vol.10 no.4 1981, pp.227-244).

It is evident that it was working-class women who were the recipients of such an education by the following, "The Queens Medals which are offered for competition throughout the United Kingdom at the general exam of science schools and classes held each year in May consist of one gold, one silver and two bronze medals for each subject. Anybody may compete, but the medals cannot be taken by middle-class students, nor by persons who are not students of science classes, nor by those who have taken the same medal before", DSA, 16th Annual Report 1868-69, p.131.

130. Lowndes, op.cit., p.43.
131. DSA, 41st Annual Report, 1894, pp.173-174.
132. Final report of the school board for London, op.cit., pp.104-05.
133. This does not take into account those schools which were mixed.
134. DSA, 41st Annual Report, 1894, pp.104-105.
135. "Committee reporting on the proposed revised New Code", BAR 1883, op.cit., p.313.
136. Royal Commission on Secondary Instruction Vol.IX, HMSO, 1895, pp.422-423.
137. Grieve, op.cit., p.2.
138. A.J. Cooper lists chemistry, physics, hygiene and physiology as the recognised subjects for girls at an organised science school. In her view these subjects gave the "theoretical side" to the practical subjects of needlework, cookery, laundery, ambulance, housewifery and nursing. Cooper, A.J., "Technical Education for Girls", Special Reports on Educational Subjects, Vol.1 1896-97 pp.187-195. Similarly, in his evidence to the Bryce Commission, Forsyth, headmaster of Leeds Central Higher Grade Board School, agreed with the Commissioners that science was not considered so necessary for girls and that "girls as a rule" were not such good science students. On being asked whether he would want to devote more time in the case of girls to domestic arts, Forsyth agreed, adding "and literary too". Evidence of J. Forsyth to the Royal Commission on Secondary Education, Vol.III, HMSO, 1895, p.193.
140. Historical records of higher grade schools and national schools were located, but these gave no indications at all about girls' science education.
141. Simon notes that the higher grade schools gave working class children some chance to reach University (Simon, op.cit., p.179). However, as MacCleod and Moseley note most of the women reading science at Cambridge were from private schools or the GPDST schools, very few came from the state schools. (MacCleod, R. and Moseley, R., "Fathers'

and Daughters' Reflections on Women, Science and Victorian Cambridge", History of Education Vol.8 no.4 1979, pp.321-333 (p.329)).

142. This point will be taken up in chapter 5; Dyhouse, C., "Social Darwinistic Ideas and the development of women's education in England, 1880-1920", History of Education, Vol.5 no.1 1976, pp.41-58, and "Good wives and little mothers; social anxieties and the schoolgirls' curriculum, 1890-1920", Oxford Review of Education, Vol.3, 1974.

143. Argles, op.cit., p.21.

144. The demand for this change came from the School Boards who wished to see drastic modifications to the grant-earning system, and from the Association of Higher Grade and Organised Science School Head Masters who, experiencing difficulties in providing a balanced education due to the regulations of the DSA, requested the provision of new courses which included literary subjects. They also advocated special science courses for girls. (Butterworth, G.L., The Influence of the Science and Art Department on the development of scientific education in English schools and evening institutions during the latter half of the nineteenth century, M.Ed. Thesis, unpublished, Leeds 1959, p.215.

145. ibid, p.219.

146. ibid, pp.219-221.

147. Report on the Differentiation of the Curriculum for Boys and Girls Respectively in Secondary Schools (Hadow Report), HMSO 1923, p.34.

148. See Widdowson, F., Going up into the next class - Women and elementary teacher training, 1840-1914. Women's Research and Resource Centre, 1980.

149. See Cook, Rev. F.C., "Special Report for the year 1850 on the College of Education Training Schools for School Mistresses", MCCE 1850-51, p.103. Banstead, J., "Report for 1854 on the Training Institute of the British and Foreign School Society in Borough Road, London", MCCE 1854-5, p.358.

150. CSIAS, op.cit., p.xiii.

151. ibid.

152. ibid, p.xiv.

153. "Syllabus of subjects of examination at Christmas 1879", RCCE 1878-79, pp.768-779.

154. ibid.

155. "Syllabus of Subjects of Examination at Christmas 1881", RCCE 1881-2, p.484.

156. "Syllabus of Subjects of Examination for Certificates at Christmas 1891", RCCE 1890-91, p.555.
157. "Syllabus of Subjects of Examination for Certificates at Christmas 1892", RCCE 1891-2, pp.566-592.
158. "Tabulated Results of Examinations, Christmas 1887", RCCE 1887-8, pp.440, 442; "Tabulated Results of Examinations, Christmas 1891", RCCE 1891-2, pp.563, 565.
159. In 1890 the total number of science exams taken by the women students was 2,237 but out of these only 220 took elementary sound, light and heat, 10 took theoretical mechanics and 53 took elementary inorganic chemistry.
160. "Syllabus of subjects of Examinations for Certificates at Midsummer 1896", RCCE 1895-96, p.325.
161. Reatchlous, H.A., "Science Teaching in Training Colleges", International Health Exhibition : The Health Exhibition Literature, Volume XIV 1884, pp.150-161, (p.151).
162. "Syllabus of subjects of Examinations for Certificates at Midsummer 1896", RCCE 1895-96, p.325.

4. The establishment and development of science education in girls' secondary education.

Introduction

However imperfect the system and however unstructured and sporadic the content and even the experience of education for working class children, there is no doubt that by the middle of the nineteenth century such children, both boys and girls, were receiving a far better education, at an earlier age, than the girls of the middle classes. Such disparity was part of the driving force behind the movement for the secondary and higher education for women[1] - a movement which generally confined its attention to those girls belonging to

> "the classes above those attending the Public Elementary Schools.....because there is abundant evidence to prove that their education is actually worse and far less adequately provided for than that of the lower class"[2].

The implicationsof such a state of affairs were drawn out by Samuel Morley M.P., who took the chair at the Annual General Meeting of the Girls' Public Day School Company in February 1877. He warned that,

> "since the education of 'the lower classes was decidedly and rapidly improving', the education of the middle classes must be 'attended to' or the lower classes would 'soon be treading on the heels of those professing to be socially above them'"[3].

The history of the movement for the secondary and higher education of women has been dealt with at length elsewhere[4]. The interest in the movement in this chapter is only in so far as it throws light on the establishment and development of science education in the girls' schools. The chapter principally seeks to explore how far science education was established in the girls schools, how it was justified for inclusion in the curriculum and how science education was being defined for girls.

Early precedents for the introduction of science education into the girls' schools.

In the 1860s, education for girls other than those of the "industrial classes" looked little different from that available in the early 1800s. The institutional emphasis was on privacy - private day or boarding schools or the service of a governess in one's own home[5] - and the curriculum emphasis was upon "accomplishments" such as drawing, music and languages[6]. Any science taught to girls was similar in form and function to that described in chapter two. This is illustrated with clarity in the report of the Taunton Commission in 1868. Joshua Fitch, in his investigations as Assistant Commissioner saw "girls learning by heart the terminology of the Linnean system, to whom the very elements of vegetable physiology were unknown"[7]. Similarly astronomy was taught "by twisting a globe round and round"[8] and, as Pederson notes, the use of the globes in this way seemed rather more adapted to "decorative ends" than any intention to give a sound instruction in either the theory of physics or astronomy[9]. Science in these schools was simply another accomplishment and this tradition lasted in some forms of girls' education throughout the nineteenth century and into the twentieth century[10].

The only exceptions evident in the pages of the report of the Taunton Commission were the curricula of two girls' schools - the North London Collegiate School for girls and the Cheltenham Ladies College, both of which included natural science. The North London Collegiate School for girls was a private school catering mostly for the daughters of professional men attending on a daily basis, with a few boarders. The headmistress, Frances Buss, had founded the school in 1850, the same year in which the North London Collegiate School for boys was founded[11]. It was later re-organised as a public school in the 1870s. By contrast, the Cheltenham Ladies College, founded in 1853, was a proprietary school, again for daughters of the upper middle class and very influenced by Cheltenham College, the public school for boys. The headmistress at the time of the Taunton Commission was Dorothea Beale, who had taken over the school and re-organised it in 1858. The school included day pupils and boarders[12]. Both the North London Collegiate School and the Cheltenham Ladies College "long-served" as models for other girls' secondary schools which developed later in the century[13].

At the time of the Taunton Commission science teaching of a sort was an established part of the main school course in both schools. Miss Buss disclosed in her evidence to the Commission in 1865 that,

> "the course includes the properties of matter, the laws of motion, the mechanical powers, simple chemistry and electricity, with the outlines of geology, botany, natural history and astronomy".[14]

The first prospectus of the North London Collegiate School shows that science was included as "The leading facts of Natural Philosophy and other Branches of Science and Art taught by means of familiar lectures".[15] The science course was conducted as "catechetical lessons" - interrogative teaching rather than didactic lectures, illustrated "by experiments and diagrams as far as possible". At this stage in the history of the North London Collegiate School the science lessons were made "the means of imparting interesting knowledge rather than of mental training". The chemistry lessons, for example, were described as "popular" as opposed to dealing with subjects like "the doctrines". Miss Buss acknowledged, however, that natural science could be usefully taught as a mental discipline although at that time, other studies were depended on for this purpose.[16]

At Cheltenham, by 1866, physical geography and different branches of natural science were taught by a Dr. Wright, F.R.S.E., F.G.S., "well known for his geological publications in the Palaeontological Society"[17]. In 1865, "he gave a course of very elementary mechanics and hydrostatics, simple mechanics etc." and it was Miss Beale's belief that "his class quite understood the structure of the steam engine in its simple form".[18] Botany was also taught stressing the physiology, circulation and structure of plants rather than simply dealing with classification.[19] A Mr. Webb, F.R.A.S., taught occasional courses on astronomy, optics and electricity[20]. Miss Beale taught Euclid to the school, without the aid of books, aiming,

> "to give as little help as possible, but to lead them on to find out for themselves; under no circumstances to let them learn by heart, and to induce them to do without explanation as far as they can, so as to call out their own powers".[21]

Apart from Euclid - which was certainly regarded as a form of mental training - the natural sciences were taught at this time "as a means of widening the views and furnishing pursuits full of interest for life".[22]

In both schools, lessons in natural science formed one part of a full school course which included English, history, geography, modern and classical languages, arithmetic, mathematics - if the pupils were sufficiently advanced in arithmetic[23] - as well as the more traditional subjects to be found in girls' education, music, drawing, art and needlework.

That these two schools were so different from the generally "meretricious character" of education for middle class girls at this time requires explanation. The first point to note is that unlike many other headmistresses, schoolmistresses or governesses, - for whom teaching was often the way out of straitened family circumstances rather than a vocation[24] - both Dorothea Beale and Frances Buss had received a reasonably thorough education themselves. Both attended Queens College which had been established in 1848 in conjunction with the Governesses Benevolent Institution to provide lectures for women in order to better train them as governesses[25]. Such experience undoubtedly contributed to their view that rather than leading girls to proficiency in various accomplishments, girls' education should cultivate the mind and induce in them the desire to study. Not only would this benefit girls' themselves - leading them to a much fuller and interesting life than was generally to be had for middle class girls at this time, but, they argued, it would also be beneficial to society[26].

Secondly, both women believed that girls were as capable of academic study as were boys, and that their minds were as worth cultivating. However, an important difference between Buss and Beale was the reasons they each held for wanting girls to be better educated. Frances Buss established her school "to prepare pupils for any position in life which they may be called upon to occupy"[27]. Her views on the education of women and girls fell into the "uncompromising" camp of educational reformers. She believed that girls' education should be equal with boys' and should enable them to lead independent lives if they chose, or were compelled to do so[28]. Frances Buss co-operated with Emily Davies in her campaign to open the Cambridge Local, Junior and Senior examinations to girls, providing twenty-five candidates for the first examinations in 1863[29].

In contrast, Dorothea Beale belonged to the "separatist" school of thought: women's brains were not inferior to men's, but because their role in life was different from that of men's, so should their education be different. Thus,

> "the habits of obedience to duty, of self-restraint which the process of acquiring knowledge induces, the humility which a thoughtful and comprehensive study of the great works in literature and science tends to produce, these we would specially cultivate in a woman, that she may wear the true woman's ornament of a meek and quiet spirit".[30]

Unlike Frances Buss, who wanted to see the examinations of the University of London open to girls on the same lines as boys, regarding them "as the only thing at all attainable at present"[31], Dorothea Beale favoured

> "a special examination for ladies up to the standard of attainment of the matriculation, but not necessarily comprising the same subjects".[32]

In spite of this divergence of views, the actual curricula of the two schools were very similar. The only differences were that mathematics was excluded from the curriculum of the North London Collegiate School in the early days because of the pupils' lack of knowledge of arithmetic[33], and at Cheltenham Latin was excluded on the grounds that "Latin, as generally taught, is (not) well calculated to develop the intelligence of girls"[34]. With the noted exclusions, the curriculum to be found in these two schools was largely influenced by the curriculum to be found in contemporary middle-class and public boys' schools. This however was no straightforward aping of the boys' schools. Neither Buss nor Beale believed that boys' education at that time provided a very good model on which to base girls' education[35], but, for Frances Buss, to choose anything except the boys' model would have been damaging to the campaign to get equal treatment for girls[36], and for Dorothea Beale, who used Cheltenham College as her model, what was suitable for the sons of "gentlemen and noblemen" was also suitable for their daughters[37].

It is not clear how far the differing views on the education of girls held by Buss and Beale were reflected in their views on science education. Given the uncompromising nature of Buss's beliefs, it could be suggested that she would have wished science education in girls' schools to match developments in science education for boys. For Beale, in her belief that a woman's education should differ from a man's because of her different social duty, it was also her belief that girls did not need as much, or the same, science education as boys[38].

From this brief sketch of the differing views of Frances Buss and Dorothea Beale, views embodied in their own schools, it can be seen how by the late 1860s two girls' schools stood ready to act as models for the many girls' schools which were established in the following two decades. The curricula and organising principles of these two schools derived in part from the emulation of existing boys' education; in part from traditional views and expectations of girls and in part from a changing philosophy of education for girls - one which stressed their intellectual capability and need for mental cultivation.

Science education in the girls' secondary schools - the influence and legacy of the North London Collegiate School.

From the beginning of the 1870s new schools for girls of the middle classes opened in fairly rapid succession. Many of these were under the auspices of the Girls' Public Day School Company (later Trust) (GPDSC(T)) which was formed in 1872. 38 GPDSC schools were founded between 1872 and 1901. The Church Schools Company, formed in 1883, established 24 schools by 1896. There were also the endowed grammar schools for girls, set up after the 1869 Endowed Schools Act which allowed for part of the funds of Educational Trusts to be applied to girls' education. By 1882, 90 girls' schools were listed as "public schools" (schools with trustees or governors, as opposed to private venture schools), and of these, only 8 were established before 1865[39]. Such schools were modelled to a great extent on the North London Collegiate School[40], which itself became public in 1871, governed by a Chairman and Board of Governors.

In spite of the apparent number of schools, it should be noted that they offered an education only to a minority of girls. Even by the end of the century, a dominant form of education for middle class girls was still in schools devoted to "accomplishments" rather than to "cultivating the intelligence". Their continued existence was due "to the widespread indifference of parents to the education of their girls, to the qualifications and training of their mistresses, and the efficiency of the schools"[41].

The new girls' high schools represented a "very real step in advance", but they were "educating but a fraction of the population"[42]. The consideration of the development of science education in these high schools is, however, important, for they and the educational philosophies produced from them shaped a particular tradition of education which lasted well into the twentieth century, both in the state sector - through the influence of the county and municipal secondary schools set up after the 1902 Education Act - and in the private sector.

It is important, at the outset, to note the aims and objectives of these schools. The GPDSC, for example, aimed "to supply for girls the best education possible corresponding with the education given to boys in the great Public Schools"[43]. How the new headmistresses defined their "Public" schools was, as Pederson argues, "not so much a precise institutional category as a complex ideal"[44]. This ideal distinguished the high schools from private venture schools, not least by the provision of advanced instruction leading to university. Further, the education in them was intended to be "liberal", that is, "to instil those qualities of mind and of character appropriate to a gentleman or lady"[45]. Indeed, the overall aim was,

> "not to fit a young lady for drawing room life, but to fit a human being through the training of her faculties, the storing and enriching of her mind, for real human life. The main object of the teaching is to develop intelligence, to call out and exercise the various faculties and thus to train habits of observation and reflection, of drawing inferences from facts; in other words forming judgements"[46].

As the girls' schools developed, documents on the philosophy behind such schools appeared. Clearer expositions of the rationale for the inclusion of science in the curriculum emerged, showing its perceived compatibility with the ideal of a liberal education. By the end of the century a diversity of aim was becoming apparent. This is shown in the views of Sophie Bryant, mistress of mathematics (1875 - 1895) and then Headmistress (1895 - 1918) of the North London Collegiate School, and

Sara Burstall, Headmistress of the Manchester High School for girls from 1898.

Sophie Bryant, D.Sc.

In her book "Educational Ends or the Ideal of Personal Development"[47], Sophie Bryant argued for the place of science in education on the grounds that "all science is the attempt to realise in thought this ideal of a self-developing whole of law"[48]. Science had its place in the development of the individual towards the ideal ends of "right-doing" and "true knowing"[49]. "The study of science" Bryant wished to demonstrate, "in general is conducted most naturally and therefore best, by the distinction of three logical stages", the stages of induction, philosophy and deduction[50]. Such a sequence, she argued, followed from the practical aspects of teaching any science other than the mathematical sciences. In these latter, "their first principles are also their elementary facts" and thus "the beginning of mathematics in a child's knowledge is, therefore, its true beginning in logical development"[51]. This, she maintained, was not the case with physics in which "the order of development from true hypothesis...is not the natural order of discovery, though it is the natural order of reflection, and the only satisfactory order to the reflective mind"[52]. As learners generally begin such studies in "not very reflective days" first principles should <u>follow</u> the study of observed facts, after which the whole should be worked out deductively. Similarly for chemistry and botany, for which "it is inevitable" the teacher should begin with the facts.

The importance of Bryant's assertions about science and logical development was in her stress on its wholeness, its "self-development of subject in logical sequence, each truth appearing as a demonstrated conclusion".[53] A teaching of science which rested on "dogmatic assertions" arising from unquestioned statements of theory and hypothesis, she argued, "breaks and defaces" the "ideal of knowledge", with the consequence that "the average student of natural science when he later comes to reject the prevailing dogmatism of his childhood is apt to content himself without any inquiry into the first principles of his subject".[54] Thus for Bryant science had an important role to play in the development of healthy minds and true individuals. Science as a method, as a "form of knowing" rather than a practical or vocational pursuit was of uppermost consideration.

In a later paper, "The curriculum of a girls school"[55], written after more than twenty years' experience of teaching, these views on science were more specifically related to the education of girls. The governing educational philosophy in this paper was familiar:

> "The school ought to offer an education calculated to develop each one in accordance with his proper end as a moral, rational and serviceable being".[56]

The uncompromising position of Frances Buss was echoed in the view that "the efficient girl is trained on the same broad lines as the efficient boy"[57], whilst recognising for both that the ideal curriculum was a flexible one which met the different needs of different pupils and that "respect should be paid in the girls' school scheme to ultimate efficiency in the housewifely and social art"[58] (my emphasis). Furthermore, Bryant argued that because "the chief function of women is the making of the home and the preservation of the social side of society" and thus less diversified than the male's future role, in the girls' school the ideal curriculum could be found "in its simpler and more universal form"[59]. Such considerations did not detract from Bryant's belief that "knowledge (is) the same to all knowers" and that unity of knowledge "in so far as knowledge per se is the end"[60] is best for both girls and boys. The question of diversity of knowledge only arose for Bryant when she considered different occupations, but in her view this was not the dominant criterion for the curriculum.

In the North London Collegiate School two science courses were developed; one for those girls "fit to carry through a complete course of study planned to fulfil a well-balanced ideal of knowledge and development" and another for those "who are only able to fulfil this ideal in part"[61]. For both courses the underlying philosophy was that science should be taught with the ideal in mind, and not for the imparting of scientific information. For both groups of girls the necessary groundwork was the "ability to observe and compare, to measure and calculate, to infer and demonstrate, to inquire into causes, to invent means, to choose ends".[62] The "limited course" involved the study of botany and natural history regularly with occasional courses on "the semi-scientific" subjects of hygiene, domestic economy and physiography. The purpose of these latter was to introduce practical interests by which the "scientific habit" could be developed "by the application of accepted scientific truths to common life".[63] The following perhaps sums up the approach to this course:

> "Herein lies the training value of hygiene as a study inferred from physiology. The inference is scientific though the premisses are dogmatically given. There should be going on at the same time, or in adjacent terms a course of reasoned botany, and the contrast between the application of science should be noted for the further inculcation of sound ideas on the nature of scientific knowledge. For even very dull learners can be taught to know where and how it is that their information falls short of the ideal of science".[64] (my emphasis).

Thus, scientific method was still the primary consideration, even though the way it was taught was more "relevant" to the perceived future of girls.

The rationale behind the "complete course" echoed very much Bryant's earlier work on the logical sequence of the sciences. Mathematics, physical and natural sciences would be taught. She argued that logically mathematics should be followed by elementary physics, then chemistry and then biology. However, she realised that because of the weaknesses of human nature, "it was necessary to take account of psychological, or, as I have called them, subjective considerations, and to allow that the foundations of biological science, which call more for observation and vivid perception than for calculation, should be - because they can be - laid early".[65] She argued that advanced chemistry was more desirable than advanced physics for an educational reason and an institutional reason. Educationally, she felt that time studying physics by the intended specialist was better spent in studying more mathematics, but her view here may well have been influenced by an institutional constraint, it was "not easy to have a physical laboratory good for advanced work in an ordinary school".[66]

Thus, in Bryant's view science had an important role in girls' education for two reasons. Firstly it was of great value in training the mind and thus aiding the growth of intellectual skill. Secondly, because of the unity of knowledge which science education could demonstrate, it could contribute to the moral development of the individual. For the less academic, a greater stress was placed on the more practical and applied aspects of science but the "ideal of science" was not absent from this "dogmatic" treatment of the subject. Importantly Bryant stressed that the only difference there should be between the science curriculum for girls and boys was in "the application of science to practice", an important consideration, but one which she argued had "inconsiderable" effect on school studies.[67]

This paper was published in 1898 and it is interesting to note how the views of Bryant changed in the following decade when certain social anxieties called for domestic education for girls.[68] Contributing a chapter on "Natural Science" to a book on public schools for girls[69], it is evident that Bryant maintained her logical, idealist approach to science as unity of knowledge, but that practical interests merited greater consideration. Thus she indicated that the chief objectives of the inclusion of science in the curriculum were,

> "that it shall lend itself with certainty and ease, to develop in the immature but plastic mind of average ability this <u>scientific attitude</u> of alert, <u>individual inquiry</u>"

and

> "that <u>the learner shall work at some nature subject in the spirit of original investigation</u>, and it is a condition on the other hand, no less to be observed, that <u>she shall not leave school in such total ignorance as to involve total lack of interest in the scheme of nature knowledge as a whole</u>".[70] (her emphasis)

But she also noted that the unity of knowledge, which was the educational ideal behind the study of science, was,

> "just now obscured by the urgency of the practical interests which it subserves in apparent conflict with the intellectual demand for systematic development in which it is rooted. Thus the dialectic uppermost for the moment in teachers' minds is between the claims of the practical and logical interests".[71]

In spite of this "urgency", Bryant proceeded to outline courses of study in which practical outcomes were incidental to the main object of the course, or were maintained in syllabuses designed for the non-specialist. Thus, for example, in the course of elementary physics, which followed nature study in the preliminary course, the study of heat, "and the simpler phenomena of pressure especially as acting on liquids and gases" was necessary for "the interpretation of everyday events" and "for the appreciation of those effects of pressure which play so large a part in geographical phenomena".[72] But their chief importance according to Bryant was that they were "necessary for the understanding of all further scientific work".[73] Similarly, in the discussion of the botany course in the senior school which required an understanding of chemical change, a preliminary course in chemistry preceded the botanical course, and such a course of chemistry was to be "studied for its own sake". Only at the end of the course were the chemical processes essential to botany to be studied specifically.[74]

In this article, Bryant repeated her view that the curriculum should not be rigid, but adapted to the needs of different pupils.[75] As in her "limited" and "complete" courses, it is clear that it was for the non-specialist science student that the "urgent" practical interests had the uppermost consideration. Thus in schools where girls left at fifteen or sixteen it was possible that their science work was

> "shaped throughout by reference to the problems of cleaning and cooking; and thus the earlier year or years will be contrived as to appeal to domestic interest and to be of domestic use".[76]

In other schools where the leaving age was higher,

> "the senior course must be so contrived as to form a complete unity in itself, and the main demand is likely to be for a course designed primarily in the interest of theoretic study to which the special study of domestic science may or may not be attached, either in sequence or as an alternative".[77]

Domestic science, or chemistry "in direct connexion with practical domestic work" or "the chemistry of domestic life" was in Bryant's scheme, very much an alternative course for girls not taking pure chemistry to matriculation standard, or for those leaving at sixteen.[78] The "natural practical interests" of girls in home-making were seen as "a powerful additional stimulus to scientific motive"[79]. For the specialist, however, it seems that no such concession to sex was made. In one school Bryant cites, about seventy-five per cent of the upper fifth form continued with the science course and selected students specialised in the sixth form. In the latter "the first year is devoted to chemistry and the second to chemistry, physics and botany at the Cambridge Higher Local standard".[80]

Bryant's views on science education, in their stress on the unity of knowledge, the growth of intellectual skill, the development of a scientific attitude and an interest in nature "as an All"[81] represented one conception of science education for girls which was established in the girls' high schools by the turn of the century. The practical aims were two-fold. First, it gave girls who were going on to university a sound, basic science education which would enable them to pass the necessary examinations and which would serve as a basis for further study. Second, it equipped less motivated or less-academically minded girls with a scientific interest and, in the rhetoric of the day, fitted them for their future home-making role. Importantly for this model of science education, at least at the level of theory, this latter practical concern was subordinate to the expressed educational aims.

Sara Burstall, LL.D.

Sara Burstall was Headmistress of Manchester High School for girls between 1898-1924. Her views on science education were undoubtedly influenced by her education at the Frances Buss schools between 1871 - 1878, first at the Camden School for girls (a middle school for girls, with a leaving age of sixteen) then for three years at the North London Collegiate School for girls. After taking a degree in mathematics at Girton she returned to the North London Collegiate School as an assistant mistress, principally teaching mathematics.[82] Like her "honoured leader Mrs. Bryant", Sara Burstall "regarded Nature as part of Divine revelation and natural science as an essential part of education".[83] Her election to the post of Headmistress at the Manchester High School for girls was explained in part because "certain governors had determined that more science should be taught in the school".[84] By the 1920s a strong tradition in science had been established under

Burstall's lead. As she recalled,

> "we had....four specialist teachers on the staff, all first class honours graduates in chemistry, physics, botany and zoology, and many Old Girls were students at universities or science graduates. Our former specialists had become university lecturers or headmistresses. Best of all a very satisfactory volume of research work stood to the credit of Old Girls which had been increased in the period since 1924. After the War we had twenty-five Old Girls in the medical courses of the University of Manchester".[85]

Like Bryant, Burstall organised the school into "A" and "B" forms with different science curricula in each. Burstall suggested that in the "A" forms, in the five year course before specialisation took place in the sixth form, nature study, biology and general elementary science should be taught. By contrast, the "B" forms should not take physics, but nature study and domestic science.[86]

Writing at the end of the nineteenth century and at the beginning of the twentieth century, a period noted by Bryant for its urgency of practical interests, Burstall's views on science education for girls appear to be much more practically orientated than Bryant's. Burstall did not doubt the intellectual capacities of girls. Every girl, she believed,

> "is a human being with a right to complete development, to a share in the spiritual inheritance of the race, to the opportunities of making the best of her faculties, or pursuing even advanced studies if she has the ability".[87]

However, in contrast to the views of Bryant, in which practical and vocational interests were distinctly secondary to the educational aims of science education, these practical interests appeared to be organising principles for Burstall. She noted that,

> "there are specialised functions in practical life for which the sexes should be separately prepared in the school....it is the natural duty of a woman to do housework and she must learn it at school".[88]

For Burstall, science education was an essential part of every girls' education, not only for its value as mental training, "but as preparation for domestic duties and the care of children".[89] This had consequences for the science curriculum;

> "For the latter duty, (the care of children), nature study going on botany and zoology is the proper subject; these life sciences are as important in the woman's characteristic activity for the young of the race as are physics and chemistry for men's industries".[90]

Burstall maintained that, generally, the specific study of chemistry and physics was not necessary for girls as they would never need them. Rather, for all girls but those who intended to specialise in science, elementary physics should be taught as "physics of the household".[91]

Thus, for Burstall, whilst science education was an important aspect of the girls' school curriculum, its importance lay not so much in its contribution to intellectual development, but in its role in preparing girls for a domestic future. The only exception to this was for those girls who intended to specialise in science. For such girls courses in physics, chemistry, mathematics and biology or botany were followed to matriculation standard.[92]

From the work of Sophie Bryant and Sara Burstall it is evident that by the end of the nineteenth century and the early years of the twentieth century three "models" of science education appeared to be in use, the educational, the academic and the practical. The educational model underpinned the other two, and embodied a conception of science education for girls as a "form of knowing", as an intellectual discipline and as a means to cultivate the faculties. The academic model functioned to enable girls with an interest and an ability in science to pursue science studies in the upper forms of the girls' schools in preparation for university entrance examinations. The practical model was generally regarded as a model of science education for less motivated or less academically minded girls, furnishing them with both a scientific interest and, particularly in the early years of the twentieth century, with the skills and knowledge they would require to efficiently carry out their domestic duties.

The extent of science education in the girls' high schools : constraints and limitations.

The work of Bryant and Burstall has been discussed at some length because it is taken here to be representative of types of science education developing for girls during this period. By the 1870s there was a "growing recognition of the claims of Natural Science" in education.[93] The Endowed Schools Commissioners informed the Devonshire Commission in 1875 that,

> "in all Endowed Schools, whether for boys or girls, we propose to require, as a specific and indispensable part of the course, at least one branch of physical science".[94]

This view was influenced by Emily Davies, who had been consulted by the Head of the Endowed Schools Commission, Lord Lyttelton.[95] The curricula thus usually found in the endowed girls' schools, and in the girls' public schools generally, included English, history, geography, French, German, mathematics, Latin and "some form of science".[96] The tendency in the history of science education has been to assume that botany was most often "the form of science" to be found in such schools[97], but some evidence would appear to dispute this. Table 5 shows the science subjects taught in the ninety public girls' schools listed in "The Educational Year Book for 1882". What is most interesting to note is the few schools which taught botany.[98] It is true that botany could have been taught in courses entitled "Elements of natural science", but, if botany was the only science taught in such a course it would be unlikely that the course would be referred to as "natural science".

If "natural philosophy", "natural science", "elements of physical science" and "physical science" are grouped together, 67 out of 90 schools included this in their curriculum, giving some weight to the assertion that the pattern of science education established by the North London Collegiate School was widely followed. However, in the same list there is some evidence of the "separatist" tradition. Physiology was often listed as being taught "with bearing on laws of health", and whilst only five schools specified instruction in this, sixty-seven schools taught one or more of "domestic economy", "household management" and "laws of health". In all of these subjects topics of a physiological nature could have been introduced.

Table 5: Science subjects taught in girls' public schools in 1882.

Subject	No. of schools which listed the subject as part of the school course.
Mathematics	49
Chemistry	7
Physiology	5
Geology	1
Astronomy	1
Natural Philosophy	3
Natural Science	40
Elements of Physical Science	22
Physical Science	2
Botany	7
Physical Geography	16
Natural History	1
Physiography	1
Zoology	1

Firm conclusions cannot be reached on the basis of one list and, as the sample curricula in the Appendix of the Royal Commission on Secondary Education (1895) shows, among the girls' schools there was considerable variation in time given to science and the branches of science pursued.[99] Generally, the first grade schools, such as the North London Collegiate School, Sheffield High School and Cheltenham Ladies College appeared to include a greater range of science subjects in their curricula, than the second grade schools, which did not aim to prepare girls for university. Far superseding both these types of school in the number of hours devoted to science education were the higher grade schools. That these schools devoted more time to science is easily explained by their funding from and influence of the DSA (noted in chapter three). What is more puzzling is the variation in time devoted to science in the girls' schools which catered for similar types of pupils, and which were linked in ideals. Such variation can perhaps be explained by the many social and institutional factors which existed acting as determinants of science teaching in girls' education.

One such factor was the need for girls' schools to attract enough pupils in order to ensure adequate funding for the continuation of the school. Thus headmistresses not only had to take into account the views of Boards of Governors on the curriculum, but also, and perhaps more importantly, the views of parents, who could withdraw their daughters instantly if they felt that the education received was not useful. How far science education was regarded as "useful" must have depended strongly on the commitment to science of the headmistress herself. Many headmistresses, however, had little or no scientific training and may have biased the curriculum towards literary subjects.[100]

Another factor was that in some schools science teaching was mistrusted "perhaps because of the apparent opposition of science and religion characteristic of Victorian thought".[101] For this reason some schools may have favoured botany - descriptive botany - as a harmless science.[102]

For those headmistresses who wished to introduce science into their school or to teach more science, there were at least two further major handicaps. One was the conflict with their broad ideal of a liberal and balanced education - science had to vie with all the other subjects for its place on the timetable. The battle which the Association of Headmistresses waged with the Board of Education over the number of hours that should be devoted to science after the 1902 Education Act, showed that although the headmistresses were not anti-science education, they were concerned at what effect an emphasis on science would have on the teaching of other subjects, particularly literature.[103] This was exacerbated by the lack of school hours. A traditional feature of the high schools well into the twentieth century was that lessons were only taught in the morning. Comparison between girls' and boys' schools of the school week at the end of the nineteenth century shows that, on average, the week for a girls' school was about nineteen hours compared with an average of twenty-seven and a half hours for boys.[104] This shorter week was felt to be a severe limitation of the possibilities for education in science for girls.

The second major handicap was the general lack of equipment for science teaching in the girls' schools, caused at least in part by the tight financing of the schools either through insufficient endowments and, or, dependence upon the number of fee-paying girls. Attention was drawn in the Journal of Education

> "to the almost universal lack in girls' schools of suitable equipment for the experimental teaching of science, owing to which girls are severely handicapped in the competitions for the scholarships tenable at Local University and other Colleges".[105]

In the same journal Miss A.J. Cooper, Headmistress of Edgbaston High School, made the point that,

> "in some few girls' schools fairly adequate provisions had already been made for science teaching, but in the cases of most, the laboratories etc., left much to be desired".[106]

For some teachers this may not have been a great problem. In the early days of the Notting Hill High School, for example, one former pupil, Dame Harriet Chick, recalled,

> "that we had no laboratories at all and girls like myself who wanted to do science had nothing. We learned science almost theoretically, but it was exceptionally well done".[107]

In spite of such successes, this lack of equipment undoubtedly had repercussions for the science curriculum. Speaking of the usual curriculum for the sixth form, Sophie Bryant noted that chemistry, biology, mechanics and mathematics were studied "because convenient". Physics "was not universally taken by sixth form science students" because of "lack of adequate equipment for the experimental treatment of this subject".[108] This was a handicap, especially in terms of some educational thinking which asserted that,

> "if a choice can be made Physics should be selected in preference to Chemistry as being a well-ordered and logical science and therefore of more value as a mental discipline".[109]

Non-material considerations are also relevant here. Many of the girls attending the girls' schools, up to the end of the nineteenth century at least, would have lacked a good primary education and thus a good foundation upon which to build a scientific training.[110] This was a problem not only at school, but also in higher education. Miss Scott, for example, a Cambridge student in the late 1880s, was placed equal to the 8th Wrangler in the Mathematics Tripos in 1890. She would have taken third place had she not been disadvantaged by "having read so very little when she came up".[111]

Such obstacles to a good science education led to criticism of what was being taught in girls' schools. One criticism was that science education only cultivated the faculty of observation and began the work too late.[112] Another, more adverse criticism, was that, with some notable exceptions, the teaching of science in the high schools for girls partook "more of show than reality" and that with the decline in the "use of the globes", the science teaching had "rather deteriorated than improved".[113]

How far such criticisms were justified is a question open to further empirical enquiry. However, that such criticisms were levelled can be of no great surprise, given the many factors which militated against successful science teaching in the girls' schools. Such factors can also partly explain why science was not a popular choice for specialisation by girls. In 1878 only 30 of the 500 women candidates for the Cambridge Higher Local examinations took science subjects. Of those women who went on to university to take science degrees between 1878 and 1911, they only comprised sixteen per cent of all London B.Sc. degrees and only eighteen per cent of the women who took a Tripos between 1881 and 1916.[114] Moreover, such women would have been drawn from a very few schools.[115] Such small numbers can also be explained perhaps by the comparative youth of science as a subject in girls' education (a factor which certainly operated in the classics-dominated public schools for boys).

In spite of these many social and institutional barriers, science education did have a firm, if not central, place in the education offered to girls in the girls' public schools. However, these same barriers served to limit the extent of that education and had implications for the actual content of the curriculum.

In the final section, this question of the curriculum will be discussed further.

Girls' science education : innovation and imitation.

By including science from the first, for the whole school, the girls' schools may have been in advance of the older, established public schools for boys, which showed "a basic reluctance to countenance science teaching".[116] In the girls' high schools, science education came under their broad concept of a liberal education. This was not so for the boys' public schools and the older grammar schools, in which for centuries the curriculum had been based upon classics, and later mathematics. The school in this tradition was a place for the building of character and the "inculcation of moral behaviour", whereas science was being advocated for its "intellectual and utilitarian value".[117] It was precisely these intellectual, and to a lesser extent, utilitarian, values, which aided the inclusion of science in the curriculum of the girls' schools. Science education was not considered contrary to the aim of producing cultured beings. It may arguably be the case that the educational value of science was recognised and accepted as an educational principle in the girls' schools before it was in the boys' schools.[118] As Sophie Bryant stated in 1898,

> "in no part of the educational field is there more living thought at the present time than in the domain of the secondary schools for girls".[119]

Indeed, by the end of the nineteenth century, in some of the first grade schools for boys, science was only part of the "Modern" side, and not considered essential in the education of all pupils. However, where science was taught in the boys schools - in the "Modern" side, and in the second and third grade schools - much more time was devoted to it than in the girls' schools.[120] That this was the case, and the reasons for its inclusion in these boys' schools curricula indicate some of the dilemmas which faced the pioneers of women's education, and indeed which face contemporary educationists.

Other than intellectual and practical reasons, there is little evidence that science was included in the girls' schools' curriculum as a pre-requisite for future professional training or occupations. In fact, it appears that occupational considerations were of insignificant influence in the early years of the high schools. Both Pederson and Dyhouse argue that it was not the main aim of the new schools, nor of the movement for the higher education of women, to increase the range of paid professional occupations open to middle class women.[121] Pederson, from the small amount of evidence she could find on this subject, suggests "that the majority of students who attended public schools before the first world war did not proceed on to paid employment and that of the minority who did, much the largest group went into teaching".[122]

Thus, science found its place in the curriculum on intellectual and practical grounds, but not for occupational considerations. However, what I argue here is that the girls' schools took on science syllabuses which were conditioned and constrained by the demands of the ascending scientific profession. Thus they were forced to comply with a specific conception of science which may have been quite contrary to the innovatory opportunities which existed in these new educational institutions. Moreover, after 1902, when science began to be a part of every secondary school curriculum, it may be the case that the girls' schools were ever more expected to adopt a conception of science and corresponding syllabuses which are now being questioned in terms of their appeal to the majority of girls and boys.

The seeds of this arguably narrow conception of science were sown in the 1860s and 1870s when pressure from the state and from the emerging science lobby was being exerted upon the Public schools to include science in their curricula. The state saw it as "little less than a national misfortune" that science was almost totally omitted from the education of middle and upper-class boys.[123] The reform of the competitive entrance examination for the army by the inclusion of science was one positive, external influence exerted on the boys' schools.[124] This, as O.H. Latter for the Association of Public School Science Masters noted in 1909,

> "led to a great increase in the number of boys learning science in the Army classes and military

> sides of the school; thus throwing a strain on both science staff and accommodation, such as to compel attention. The outcome of this has been the augmentation of the science staff and erection of new laboratories and science classrooms by many schools....the general scientific equipment has now been greatly improved, and increased facilities are now enjoyed by classical and modern sides as well as by Army candidates".[125]

Another influential external pressure was that brought to bear by the science profession itself. This had very pragmatic reasons for promoting the teaching of science in schools.[126] In the 1830s Charles Babbage had declared that science in England was in decline not so much because there were few practitioners, but more because of the lack of institutional support and social recognition.[127] It became clear to the scientists that,

> "if (science) were to affect the outlook of society as a whole it would have to penetrate the existing educational structure from primary school up. Not only would entrance into the instructional system provide many new positions for scientists, a factor not overlooked by the partisans of the advancement of science, but it would also aid in attaining recognition and appreciation for scientific activity and would serve as a means for recruiting new members to ranks of science".[128]

Thus two things occurred. One was that scientists began to attempt to modify the rigid concept of a liberal education by arguing that a full training of the mind was only possible by the inclusion of science.[129] In order to overcome the problem of the utilitarian nature of science which tainted its educational merits, arguments were constructed which stressed the purity, abstractness and independence of science as a body of knowledge and yet which also showed the dependence industry had upon the pursuit of that particular form of knowledge.[130] On another line of attack the BAAS made its own investigations into the state of science education - in which consideration of girls' education was noticeably lacking - publishing influential reports in 1867, 1888, 1889 and 1890.

Such pressures for the development of science education lead to the conclusion that the early school science syllabuses were based on a conception of science which stemmed from professional interests. If it is the case that what Turner refers to as "public science" - the rhetoric and argument to justify activities to political powers and social institutions by scientists - became more civic minded and state orientated in the mid 1870s expressing the values of "collectivism, nationalism, military preparedness, patriotism, elitism and social imperialism"[131] it is perhaps possible to understand that the inclusion of science in girls' schools on the grounds of its intellectual qualities and yet its practical import to properly fulfil woman's domestic role, adopted a view of science being advocated by scientists and the profession as a body.

If this view is accepted, the question is whether this really mattered. In the light of contemporary discussions on "girls and science" which suggest that for girls at least science courses which relate to the social context are more appealing, such a narrow conception of science as was finding itself in the schools, "modelled on the needs of the few pupils who (intended) to proceed to the University",[132] could only fail to embrace the interests of the majority of pupils. This was so particularly for girls as at that time they had no great reason to believe that science was absolutely necessary to their future.[133]

In this sense, the schemes of Mrs. Bryant, which drew upon the "natural practical interests" of girls to motivate their interest in science and thus enable the teacher to lead them to higher educational ends, may have been quite innovative in ways in which the boys' schools were not. However, as will be discussed below, the terms in which such interest was motivated - future domestic life and its requirements - served only too well an alternative, separate conception of science for girls. Before this is discussed, it is necessary to examine why the girls' schools were not more innovative.

To some supporters of the movement for the secondary and higher education of women it was a matter for regret that the new girls' schools did not make greater use of their opportunity to move away from the outdated curriculum of the boys' schools to experiment with new courses and methods.[134] However, as a strategy at a time when the idea of education and higher education for girls of the middle classes was vehemently opposed, the proponents of education for girls were forced to proceed pragmatically "not seeking to raise large questions of principle, but hoping to solve practical problems, make limited points acceptable to all but the most entrenched and irrational opposition".[135] As a note in the "Journal of Education" for April 1888 stated, the pioneers of secondary education for women "have been forced,for the sake of asserting their rights,to don male attire".[136] Sarah Burstall, recalling the early days of women's education justified this strategy at that time, because "progress would have been impossible without it".[137]

There were two reasons at least why conformity to a particular curriculum and thus, it is suggested, to a particular approach to science was necessary. Firstly, to develop a new pattern of education, different from the existing education for boys, was regarded - with a perceptive insight into the distribution of social power - as a dangerous move. Emily Davies and her colleagues knew that if special examinations, or special regulations existed for girls, girls' education would "always be assumed to be less strict and less exacting whether it was or not".[138] In this way girls and women would be left with "a separate kind of education which would be considered inferior to men's and women would never be able to prove that it was equal to that of men".[139] Secondly, in matters of curriculum, the existence of external examinations, supervised by the universities, exerted considerable influence. Preparation for examinations such as the Junior and Senior Cambridge Locals, College of Preceptors examinations and the London matriculation examination was an important feature of many of the girls' high schools,[140] not least "because in the eyes of the world at large and also of many pioneers of women's education, the capacity to pass examinations was the sole criterion of the educability of girls".[141] Little evidence is available on what subjects girls took in these examinations. Evidence is available, however, to show that science subjects were slow to be taken up by candidates entering external examinations[142] so it can be supposed that science was not the first choice for examination by many girls, until perhaps the last decade of the nineteenth century when more candidates from girls' schools were entered.[143] In spite of the lack of information on this point, it is clear that the existence of examinations had several effects upon the school curriculum. They probably helped to ensure that science teaching became more methodical and systematic, but they also determined what was taught.[144] They "forced a certain kind of uniformity on science teaching, making innovation comparatively difficult".[145] They also gave power to the universities to influence what was taught in the science curriculum with the result that the science course in the sixth form often served as a pre-university qualification.

Thus the women pioneers were not greatly innovatory in their schools and generally conformed to an existing pattern of education established in the boys' public schools and the universities. They were constrained either by the socially delicate nature of their campaign, or, as has been argued by some historians, by the fact that revolutionary change was not their intention, but rather, a desire to raise their professional status.[146] In either view, the only alternative to this traditional "male" curriculum was one which did not drastically confront social ideas about women and yet which allowed for the professional opportunities for which the women's movement campaigned. As Dyhouse has commented,

> "it was highly unlikely that (the) men and the other social groups who supported new educational ventures for women would have done so had these ventures set out to challenge the conventions of family life, or even, to any substantial extent, to challenge conventions about acceptable "womanly" behaviour or concepts of femininity".[147]

Thus women and girls in secondary and higher education were bound by "double conformity", having rigidly to adhere to two sets of standards, "those of ladylike behaviour at all times, and those of the dominant male cultural and educational system".[148] Whilst one strand of the movement, represented by such women as Emily Davies and Frances Buss, maintained that it was imperative that women follow exactly the same path as men; another, equally vocal current promoted the notion of "separate but equal" demanding "courses for women which were particularly suited to their future as teachers, nurses and mothers".[149] It was women's duty, in this view, to make "their late-earned, sorely grudged privilege of education subserve the great purpose of fulfilling worthily their divine mission as mothers".[150] The implications for science education, as seen in the views of Sara Burstall, were clearly that such education should furnish scientific principles applicable for the care of the children and the better functioning of the home. Within the girls' schools themselves both philosophies became embedded in the curriculum. For those girls who were intending to specialise in science, academic courses developed on the same lines as courses in boys' schools, whilst for those girls who were less intellectually capable or who were less motivated, courses drawing on a girls' "natural practical interest" developed. By the beginning of the twentieth century it appeared obvious to one section of opinion within science education that a "domestic science" would best serve the needs of the majority of secondary school girls.

Science education in girls' secondary schools.

From the 1870s a network of girls' high schools was established. The North London Collegiate Girls' School acted as a model for many of these new schools. From the beginning science education was included in the curriculum of these schools, and most often one or more branches of the physical sciences were taught as well as mathematics.

The attempt here has been to show that the institutional context of the girls' schools and the social context in which they developed, were strongly influential in shaping science education for girls. Furthermore, in spite of the innovatory potential of the girls' schools, they tended to embrace the type of education, including the science education, which was to be found in the corresponding boys' schools. The women teachers were caught in a double bind, having either to conform to these standards set up in the boys' schools in order to prove girls' ability; or to develop conceptions of science education for girls which were particularly suited to predominant notions of girls' needs - needs related to their expected domestic futures.

Thus, by the beginning of the twentieth century, science education for girls of the middle classes in the girls' high schools was taking on two forms. For the academic, able and interested, the possibility existed of pursuing science in highly specialised courses leading to university. For others, alternative courses stressing the scientific aspects of domestic life were developing.

The developments in the girls' high schools were important for the example they gave to other schools of a similar nature established after the 1902 Education Act. From them a tradition was carried which stressed the intellectual and practical advantages of science and its compatability with a liberal education and the goal of developing the individual mind.

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106. "6th Conference of the Teachers Guild, Bath 1894", Journal of Education, Vol.XVI 1894, p.87.
107. Quoted in Kamm, 1971 op.cit., p.177.
108. Bryant, 1911, op.cit., p.134.
109. Laurie, A.P., "On Science Teaching with special reference to Chemistry", Journal of Education, Vol.XII 1890, p.541.
110. In his evidence to the Bryce Commission, David Forsyth, Headmaster of Leeds Higher Grade School, noted that many girls came to his school at 13, 14 and 15 from private schools and "not having had any thorough training before....we have very great difficulties with such girls". Bryce Commission, op.cit., Vol.III 1895, p.191.
111. Sharp, E., Hertha Ayrton - A Memoir,
112. Walter, L.E., "The Teaching of Science in Girls' Schools", BAR 1896, p.761.
113. Mackintosh, D., "On the Introduction of Science into Higher and Middle-Class Schools", BAR 1883, p.622.
114. McLeod, R. and Moseley, R., "Fathers and Daughters : Reflections on Women, Science and Victorian Cambridge", History of Education, 1979, vol.8 no.4, pp.321-333 (pp.324-325).
115. Bryce Commission, op.cit. Vol.IX 1895, pp.428-429.
116. Meadows, A.J. and Brock, W.H., "Topics fit for gentlemen : The problem of science in the Public School curriculum", Simon, B. and Bradley, I., (eds.), The Victorian Public School - Studies in the Development of an Educational Institution, Gill and Macmillan, Dublin 1975, p.110.
117. ibid., p.113.
118. "Now that the large number of subjects included under the head of science are more reasonably taught to elder boys and others, there has arisen a

fairly widespread feeling amonst both parents and schoolmasters, that some elementary information on scientific subjects should be given to boys whilst still at Prep. Schools, and that these subjects afford valuable material for educating the minds of such boys. To their credit be it said, Board Schools and Girls' Schools have for some time realised this fact and in many of them scientific subjects find a place in the curriculum". Vassall, A., "Natural Science in Preparatory Schools", Special Reports on Educational Subjects, Vol.6, 1900, p.257.

119. Bryant 1898, op.cit., p.99.
120. Thus accounting for the comment in the Hadow Report that up to 1904 the girls' schools were behind the boys' schools in the teaching of science. Hadow Report op.cit., p.33.
121. Pederson op.cit., p.575; Dyhouse op.cit., p.57.
122. Pederson op.cit., p.565.
123. Meadows and Brock op.cit., p.111.
124. Latter, O.H., Report on Science Teaching in Public Schools Represented on the Association of Public Schools Science Masters, Board of Education, Educational Pamphlets no.7, HMSO 1909, p.7.
125. ibid.
126. Mendelsohn, E., "The Emergence of science as a profession in 19th century Europe", in, Hill, K. (ed.), The Management of Scientists, Beacon Press, 1964, p.42.
127. ibid., p.30.
128. ibid., p.42.
129. See the discussion of "The Scientific Movement", in Archer op.cit., pp.108-145.
130. Mendelsohn op.cit., pp.34-5.
131. Turner, F.M., "Public Science in Britain, 1880-1919", ISIS, vol.71 1980, p.592.
132. Report on the Position of Natural Science in the Educational System of Great Britain, op.cit., p.21.
133. This view is supported by a comment in the Hadow Report which stated that up to 1904, girls "had not the same practical reason for studying science". Hadow Report, op.cit., p.33.
134. Burstyn, J., Victorian Education and the Ideal of Womanhood, Croom Helm, 1980, p.158.
135. Bryant, M., op.cit., p.82.
136. Journal of Education, vol.X 1888, p.176.
137. Burstall 1933 op.cit., p.55.

138. SIC op.cit., p.142.
139. Burstyn, 1980 op.cit., p.152.
140. See The Educational Year Book for 1882, op.cit.; the majority of girls' schools listed provided instruction for one or more of these examinations.
141. Hadow Report op.cit., p.27.
142. Cane, B.S., "Scientific and technical subjects in the curriculum of English secondary schools at the turn of the century", British Journal of Educational Studies, vol.8 1959, pp.52-64.
143. Oxford and Cambridge Schools Examination Board, Summary Report on the work of the Board during the thirty years 1874-1904, Clarendon Press, 1904, p.20.
144. In her evidence to the SIC for example, Frances Buss explained that "Botany has recently received very much more close attention because it is a subject which would tell in the Cambridge examinations"; and also that the lessons were made to suit what was "demanded by the Cambridge examinations for a pass". SIC op.cit., p.266.
145. Brock, W.H., "School Science Examinations - Sacrifice or Stimulus", in, MacLeod, R., Days of Judgement : Science Examinations and the Organisation of Knowledge in Late Victorian England, Nafferton Books, 1982, pp.169-188 (p.179).
146. This is discussed in Bryant, M. op.cit.; Pederson op.cit., and Milburn op.cit.
147. Dyhouse op.cit., p.57.
148. Delamont op.cit., p.140.
149. Shirrif, E., "What is women's work in the world?", Journal of Education, Vol.X 1888, p.519.
150. ibid.

5. Science or domestic science? The struggle to define an appropriate science education for girls in early twentieth century England.

Introduction.

At the opening of the twentieth century the notion of "domestic science" began to receive considerable attention in relation to concerns about what constituted an appropriate science education for girls. This was contemporaneous with developments in education which both made a clear chronological distinction between primary and secondary education and which set the seeds for the establishment of secondary education for all. Broadly the term "secondary education" and the title "secondary school" denoted schools for pupils up to the age of sixteen, offering an academic curriculum with the aim of providing a liberal education.[1] Following the 1902 Education Act the provision of secondary education was expanded primarily by the establishment of the municipal and county secondary schools. These remained fee-paying schools which, in spite of the "free-place system" introduced in 1907, catered mainly for the middle classes.[2] The opportunities for higher education for working-class children were generally restricted to what was termed "post-primary" education - higher standards in the elementary schools, higher elementary schools, central schools and trade and technical schools. Such schools, in the tradition of the earlier elementary schools, were strongly vocationally orientated with a lower leaving age of fourteen.[3]

In this way, the expansion of education at the beginning of the twentieth century tended to be an expansion of opportunities for children of the middle classes to receive a "liberal" education, and the extension of vocationally orientated education for children of the "industrial classes". This is a significant point in the consideration of the struggle to define an appropriate scientific education for girls. The chief questions to which this chapter is addressed are firstly, whether "domestic science"[4] took its place with other sciences in the curriculum and secondly, how much it influenced the development of girls' science education.

Background to the development of domestic science.

At the opening of the twentieth century a new interest in domestic science emerged relating to public fears about the degeneracy of British society and the British race and to the concern that some form of domestic education should feature in the education of all girls. The teaching of domestic subjects to girls was widely regarded as a panacea for the perceived decline of home life and the belief in the subsequent disintegration of society. Throughout the nineteenth century the number of working class women working in the mines, factories and various other trades led to claims that the standard of housewifery had fallen along with the standard of morality among the working classes. It was claimed that children were improperly cared for and that men found the public house more attractive than their own uncleaned hearth. Such was the emphasis on the home and motherhood as pillars of society, the grinding poverty and appalling living conditions of working people were rarely mentioned. Among the middle classes, the success of the movement for the secondary and higher education of women in the 1870s and 1880s led to the complaint that girls were no longer able to learn the domestic arts within their own homes. Furthermore, it was argued that such knowledge was not being gained at educational establishments either because these tended to spurn housewifery in favour of more intellectual pursuits.[5]

In the early years of the century the fears underlying these claims were fanned by the report of the Inter-Departmental Committee on Physical Deterioration published in 1904. In this report attention was drawn to

> "the extremely low standards of living and fitness apparent in the congested central districts of larger towns and cities. In accounting for these conditions, the authors of the report laid heavy emphasis on the habits and domestic organisation of the inhabitants. Women in particular were blamed for their ignorance of household affairs, hygiene and nutrition, their diminished sense of maternal obligation and their wrong-headed notions of infant care."[6]

As in the nineteenth century a causal connection was made between the high level of infant mortality of the time and the employment of married women.[7] The view was held that the proper context of childhood was the family and the person most responsible was the mother, thus it was her fault if the infant did not survive. The solution to the problem of public health and infant mortality "was looked for in terms of individuals, of a particular role - the mother, and a social institution - the family".[8] This period saw the formation of an ideology of motherhood in which was incorporated nineteenth century assumptions about women, domesticity and individualism. A woman's role as mother was that which was most heavily stressed.[9] Davin argues that "the relationship between family and state was subtly changing. Since parents were bringing up the next generation of citizens the state had an interest in how they did it. Child rearing was becoming a national duty, not just a moral one".[10]

The 1904 Inter-Departmental Committee report clearly stated that a solution was to be found to the problem by ensuring an appropriate education for girls which would "raise the standard of domestic competence" and "underlie the importance of proper ideals of home life among young girls destined to become the wives and mothers of the future".[11] In 1906, Mrs. Margaret Pillow, a committee member of the Association of Teachers of Domestic Science (ATDS), took up this theme in an address to the educational section of the BAAS. Her talk, "The duty of education authorities to the nation respecting the teaching of domestic subjects" embodied seven points:

> "1. The growing distaste for home life.
> 2. The shirking of domestic duties by girls and desire for outside occupation of any kind not involving domestic responsibilities.
> 3. The decrease (in the number) of marriages.
> 4. The falling birth rate.
> 5. Infantile mortality, resulting from ignorance on the part of mothers respecting diet, care of infants etc.
> 6. The means for teaching girls domestic subjects a) in the past, b) at present.
> 7. The definite duty of the education authorities of this country to make provision for teaching the domestic subjects and the management of the home to all girls in their schools as an essential part of their education."[12]

Mrs. Pillow's final point focussed attention on education in domestic subjects for all girls and all types of girls' schools including the girls' secondary schools. Like many others of the period, she was concerned to remedy the fact that hygiene and domestic economy were not centrally established - if present at all - in the curricula of secondary schools for girls. This was in sharp contrast to the public elementary schools, which since the 1870s had included domestic economy in the curriculum for girls. The term "domestic science" was used for the first time in the regulations of the Committee of Council on Education in 1897-8 when it was introduced as a new specific subject in the public elementary schools. Here it was meant as "the science of domestic economy and hygiene treated experimentally".[13] The scheme, formulated by William Mayhouse Heller, science demonstrator for the London School Board, intended that all the experiments,

> "be carried out as far as possible by the scholars themselves, each experiment being arranged with the object of solving a definite problem. The lessons deal with the science underlying many of the rules and operations of the household and are aimed at presenting the facts connected with the subject of domestic economy upon a reasonable basis, thus training scholars to observe critically, to think accurately and to form correct judgements".[14]

The scheme was originally devised in response to a request by Henry Holland, Headmaster of a mixed school in Hackney "to do something for the girls in his school by way of experimental work touching Domestic Economy".[15] This course of lessons attracted much attention from other science educators as a good example of how science education could be improved in the elementary education system "as a preparation for technical studies".[16]

Following the 1902 Education Act and the expansion of secondary education more girls were to be found in the girls' secondary schools. It was obviously worrying to some authorities that one section of the female population should have no education in subjects thought crucial to the nation's well-being. This, however, was not the only motivation for the move to introduce domestic science into the girls' schools. The early years of the twentieth century were also years in which "the aims, content and methods of science teaching were subject to mounting scrutiny".[17] For a leading and influential exponent of domestic science, Professor Arthur Smithells, Professor of Chemistry at the University of Leeds, it was thought that the subject could achieve two things at once. In his address to the British Association in 1906 on "School Training for the Home Duties of Women", he argued that domestic science could firstly, reform the science teaching which prevailed at the time which remained "for the most part formal and academic in its scope" and completely unsuited to the needs and interests of the ordinary girl; secondly, it could introduce into "the stale, flat teaching of domestic economy a solid, scientific foundation". The benefits of such a course would be that the subject matter would be linked "much more definitely and thoroughly to what will normally be the chief business of (girls) lives".[18]

Contemporaneous with these fears and anxieties about the degeneracy of the British people and the Empire and with desires to see a reform of science education was a social atmosphere in which science was developing as the dominant form of knowledge.[19] The notion of "efficiency" became almost synonymous with "science". It was logical then that at least one section of educational opinion should promote a concept of science for girls based on domestic application. By treating domestic subjects scientifically not only would scientific knowledge be imparted, but girls would learn to be efficient housekeepers and mothers.

Educational factors favouring the development of domestic science.

The interest in the reform of teaching methods and curricula was widely shared in the early years of the twentieth century.[20] It was recognised by many that the traditional secondary curriculum, including the science curriculum, was generally too formal and academic for those children who would be leaving school at sixteen to take up industrial or commercial occupations.

Sara Burstall, for example, writing in the journal "School World" in 1910, detailed the pressures on the school curriculum with new subjects putting pressure on the time table and the number of pupils leaving school before they had completed their course of study. It was necessary in her view to revise the curricula and to modify the "too academic character of secondary education" and to "provide variant courses of study for different types of pupil".[21] Within science education this view was supported by the Board of Education which felt that in schools in which school life ended at sixteen it was "plainly desirable that the syllabus should represent something more than the initial stages of a study which the pupils will never continue; that it should have, in fact, a purpose and completeness of its own".[22] For Smithells and his supporters, the tradition of science education in girls schools which came straight from the boys schools and the universities, led to a formal treatment of the subject which was "very futile (and) Chemistry and Physics as ordinarily presented to school girls were not acceptable; they did not appeal to any logical faculty nor to any feminine interest".[23] His advocacy of a science relating to domestic application corresponded well with contemporary discussions on the association and correlation of subjects. In the Board of Education's Annual Report for 1909 attention was drawn to the desire to relate science to other subjects taught in the curriculum such as mathematics, mechanics, manual instruction, geography and domestic economy. In the same year the Board set its Consultative Committee the task of considering the place of practical work in secondary schools - a task which took five years to complete, but which gathered much information on actual school courses which were attempting to correlate the teaching of science and domestic subjects.

The belief that instruction in all aspects of home life should be "regarded as a necessary and essential feature of a girls' education"[24] was another strong educational factor influencing the Board of Education. In their annual regulations it was laid down what subjects were to be taught in the secondary schools and the minimum time to be devoted to each subject. From the publication of the regulations for secondary schools in 1904 it was stated that instruction must be given to girls in housewifery but that also not less than seven and a half hours a week were to be for science.[25] By 1909, however, the Board had made it progressively easier for domestic subjects to take the place of science and mathematics for girls over fifteen. In 1907 the reason was given that this was in order to "emphasize the importance of practical training for life in the case of girls",[26] and in 1908, "in order to emphasize the importance of training for domestic duties in the case of girls".[27] In 1909 the regulations allowed that "for older girls science may be dropped and mathematics restricted to Arithmetic in order to make room for a fuller course in these domestic subjects",(i.e., needlework, cookery, housekeeping and household hygiene).[28] In 1904 the Association of Headmistresses (AHM) had objected to these regulations on the grounds that too much time was given to science and that housewifery should not be a compulsory subject in a four year course.[29] Such objection was not a rejection of science education for girls or of the teaching of housewifery, but rather opposition to the curtailment of the freedom of headmistresses to decide upon their own curricula and against what they saw as an imposition of a rigid, uniform and stereotyped curriculum. Such a curriculum was felt to upset the traditional balance of subjects and recreational pursuits which characterised the high schools.[30] The Board went some way to meet the objections of the AHM and it was satisfied with the revised regulations of 1905 which stated that of the requisite seven hours for science and mathematics only two were required for science. In 1907 the Board ceased to make detailed directives about the time-table and the curriculum. The headmistresses were at greater liberty to determine their own curricula within the Boards' more general rule that "the arrangement of work must provide for due continuity of instruction".[31]

It is suggested here that with the pressures on the school time-table, along with interest in the reform of teaching methods and the growing belief that all girls should receive instruction in domestic subjects, educational opinion by about 1905 appeared favourable to the notion of domestic science. At one and the same time this could reform the traditional science curriculum for girls, quell anxieties about the level of domestic skill in the female population and reduce pressure on the time-table.

Domestic science as a school subject.

In spite of this interest in domestic science there is little evidence that one can speak of a coherent movement for the teaching of domestic science within secondary schools. Generally attempts to teach domestic science tended to be individual and isolated; it was in no sense a standard or uniform subject. The most detailed information on domestic science as a school subject comes from two Board of Education reports, the 1911 "Interim Memorandum on the Teaching of Housecraft in Girls' Secondary Schools", and the subsequent report of the Consultative Committee on "Practical Work in Secondary Schools", published in 1913.

Where domestic science was found in the school curriculum, as the authors of the 1911 Memo stated,

> "The course may consist of little more than an ordinary course of Experimental Science (corresponding to the first two years of an ordinary Science Course) with

> certain items in the Chemistry section of it, which fit in with housecraft requirements, tacked on at the end; or it may consist of a course in which the housecraft bias is dominant throughout, a course consisting in fact of a kind of 'Applied Science' from the outset. It is often quite impossible to decide from a mere inspection of the syllabus what the nature of the 'Domestic Science' work attempted precisely is and the use of the term in connection with any given syllabus is no guarantee of the character of the work that is actually done".[32]

In some cases the science work was regarded as predominant over the housecraft and in others the opposite principle ruled; thus when the 1913 report was published it noted general agreement between its witnesses on the natural connection between science and certain of the domestic arts and the "desirability of developing educationally the sense of its existence".[33] It also noted, however, the controversy which existed on "the method of correlating these two branches of work".[34] One more practical view stressed the need for the introduction of system and method to a formerly unscientific and illogical pursuit, whereas the other view, influenced strongly by Smithells saw the domestic arts as the way to make chemistry and physics both more relevant and appealing to girls. Indeed the evidence to the committee points to at least four different approaches to the two subjects of science and domestic science for girls; as a combined course, as cookery/housecraft with a scientific bias, as science with a domestic bias and sometimes with a separate cookery course or a post-school course or, finally, science and housecraft as two distinct courses.

Claims and counter claims.

It is hardly surprising that no clear definition of domestic science was evident in practice at this time, given the controversy which surrounded the subject. Educational journals such as the 'Journal of Education' carried many items of news, letters, articles and opinion on the subject particularly between the years 1905 to 1915. The central arguments against domestic science were that it was not good science and it could not achieve what science education ought to achieve.

Science had found its place in the curriculum of the girls' high schools because of the belief in its value as a mental discipline.[35] The fear was that, whilst "the acquisition of knowledge leading up to the chemistry of domestic life" was supremely attractive for "the practical mind intent on finding out how things are to be done and why",[36] as an intellectual training, the difficulty of domestic science was in "the presentation of logical development either as systematic thought or consecutive discovery".[37] In the 1911 Memo the view was stated that domestic science courses could "easily degenerate into simple observational work coupled with 'useful information'", thus losing the intellectual merits of a science course.[38] Ida Freund, science tutor at Newnham College, Cambridge, in her cutting criticism of domestic science in the feminist journal "The Englishwoman", stated that it was "erroneous to think that through the study of the scientific processes underlying housecraft and especially cookery, you can teach science, that is give a valuable mental training which should enable the pupils in after life to judge whether an alleged connection between effect and cause has been established or not".[39]

In December 1911 a Mr. H.J. Hartle of Homerton College, Cambridge, had written to the Journal of Education endeavouring "to show the dangers of attempting to use the complex physical and chemical changes met with in cooking and cleaning as the basis of training in scientific method".[40] In July 1912 he wrote a second time in response to a book which had recently been published by Mr. R.H. Jones, Dalton Scholar of Manchester University and Head of the Chemical Department, Harris Institute, Preston, which was "intended for domestic science schools and girls schools generally" and was based upon the view that "science can be directly and adequately taught in the kitchen and that a previous training in elementary science is not indispensable".[41] He then proceeded to demonstrate the "loose phraseology" and "dogmatic statement" such as "distilled water contains nothing and is quite soft; fruit contains as a rule 80% of water and this is in a pure condition", "infants and young children require very little solid in food or solid food", "a colourless liquid collects: it is water". Another complaint was that "what idea of the nature of scientific proof can the student gather from experiments in which one property, and that a property shared by many other examples, is used to determine the identity of a substance?". As an example he gave the following,

> "in one experiment the presence of tannin in tea is demonstrated. On repeating with coffee and cocoa, one is told that 'almost similar results are obtained, and so the presence of tannin in each is demonstrated'. In the same chapter we find another experiment with cocoa. On heating, cocoa is found to give rise to fumes which turn red litmus blue. This we are told is 'an alternative method of testing for protein'. Is sal-volatile, then protein? I would ask."[42]

In another educational journal, Miss E.J. Woods wrote of the inability of science to account "for many aspects in the so-called 'simple' phenomena of daily life....Such common processes as bread-making and soapmaking are extremely complex and each constituent factor is of a highly intricate nature; hence even if Organic Chemistry had so far failed to explain these processes we could never hope to make them clear to the mind of a child or even to that of an unscientifically trained (sic) adult".[43] Even when introducing topics like soap into the course for her students at Newnham, Ida Freund found that "the interest is so exclusively concentrated on the mechanical process that the scientific object is almost lost sight of, and the net result is that, for the time at any rate, there is no intellectual gain whatever".[44]

Similarly Sir William Tilden, lecturing to the London Section of the Science Branch of the Assistant Mistresses Association, said that the value of chemistry was that it taught measurement and the principles of classification, whereas applications were not easy. Thus he doubted "whether domestic science can form a proper University faculty. Children cannot verify all first principles and must take some for granted".[45] This "taking things for granted" was faulted, not only because it made "the inculcation of scientific method impossible"[46] or led to a situation whereby chemistry became "a purely memory subject to be forgotten as soon as the girl leaves school",[47] but also because the introduction of chemical topics to correlate with a home science course tended to "introduce chemistry quite beyond the real comprehension of girls of school age, and completely ignoring most of the important and easily grasped portions of the fundamental science, physics".[48]

Such criticisms were not without their rejoinders. Sir Arthur Rücker, closely involved with the establishment of Kings College for Household and Social Science, in a written reply to Freund's criticisms,[49] noted that her arguments had "mutatis mutandis, all been heard before, whenever a new branch of technology or of practical teaching has been introduced into our system of higher education". He likened domestic science to engineering and the same distrust with which it had originally been received, and likened his advocacy of domestic science to a mission of those who would not be turned back by "the old cries of 'smattering' and overfull curricula and the like". Their wish was to "give to girls desiring to prepare for their probable futures as guardians, heads of institutions, members of County Councils and their committees or managers of their own households, the same belief in the vital utility of the facts they study that the young engineer enjoys". Rücker agreed that there were difficulties, but "they will be overcome in the case of domestic science if women will show that they have the same initiative, the same resourcefulness and the same power of distinguishing between the desirable and the essential which engineers have displayed".[50]

Some of the difficulties which the critics of domestic science identified were dismissed by its advocates many of whom rejected the notion that the majority of girls required the sort of intellectual training that the science mistresses believed in. Science for girls should be "educational....stimulating and real".[51] John Wilson, Head of the Chemistry Department of Battersea Polytechnic, claimed that the criticism was "unduly severe and pedagogically unsound so long as it is clearly understood both by the teacher and pupil that only 'broad outlines' or explanation" were the aim.[52] R.H. Jones, who was explicit in his belief that domestic science courses were more worthwhile and relevant for girls than the academic courses which prevailed, retorted to Hartle's complaints that "pure and applied science may be so deftly interwoven that interest is maintained throughout".[53] Margaret McKillop from Kings College for Women refused to concede the monopoly of scientific understanding to the traditional science course and pointed out "that it was perfectly possible to make the outlines of the changes occuring in for example saponification clear to a class that had been well-trained in elementary chemistry and had further made acquaintance with some typical organic compounds".[54]

Thus the claims of those who favoured the introduction of domestic science were that it could reform the too academic treatment of science in girls' schools which was generally geared to the minority of girls proceeding to university and it could make the science more relevant and interesting to girls whose futures they assumed would in all probability embrace running a home and raising a family. Moreover they argued such a science could lead to future study itself and professional qualifications for those women wishing to pursue a career.

In spite of such claims, strong opposition to domestic science came from the female science teaching profession. This opposition, as Christina Bremner, a contemporary writer on education, noted, was rooted in the fear that "science, by invading the home (would) cut off the valuable privileges that have been won by the pioneers of women's higher education".[55] Such fears were articulated through the channels of the Association of Assistant Mistresses (AAM) and later the Association of Science Teachers (AST).[56] These bodies, at this time were dominated by teachers from the girls' public secondary schools and, in the case of the AST, lecturers from London University and Newnham and Girton Colleges. They were largely bodies of graduate women concerned to defend their hard won right to an intellectual education on a level with men. The educational establishments with which they were involved espoused the philosophy of an academic training on the same lines as boys and the strict insistence on the primacy of the "scientific attitude of mind". It was not that they were opposed to the teaching of domestic <u>subjects</u> at school. Florence Storr, science mistress at the Central Foundation Girls' School, London, later to be secretary of the AST in 1918, wrote, for example, of the "desirability" and "feasibility" of introducing domestic subjects into the curriculum,[57] but in regard to domestic <u>science</u> the women teachers were more than cautious about a subject which threatened to eclipse the progress they had made in developing science studies at school and in sending girls to university to read science.

This caution was also shared by the representative body of domestic subjects teachers - the Association of Teachers of Domestic Science (ATDS) - which had developed out of the technical sub-committee of the National Union of Women Workers, in 1897.[58] Open to "teachers of domestic science holding diploma and certificate from recognised training schools",[59] the composition of the association and the background of its members was very different from the AAM or the AST. However, just as the science teachers feared that domestic science would encroach on their hard won position, domestic subjects teachers feared a narrowing of the educational possibilities embraced in the term "domestic arts". Judging by what appeared to be an internal struggle within the Association, the majority of members were happier with the term "domestic subjects". In 1909 the name of the Association changed to the Association of Teachers of Domestic Subjects.[60]

The suggestion that science and housecraft should be correlated and that the science mistress was in the best position to teach domestic science[61] not only threatened to undermine the position of women science teachers and science teaching in the girls' schools, but also the more fragile position of the housecraft mistress.[62] Science mistress, Miss F. Martin-Leake, wrote to the Journal of Education in 1911 pointing out that science mistresses "would have neither the time nor money to spare to qualify as a teacher of domestic economy also".[63] She also echoed the views of both the domestic subjects teachers and the science teachers in stating that "an important point to be realised as soon as possible is that the same mistress cannot teach both groups of subjects".[64] This was a conclusion that had been reached some time earlier by a subcommittee of the ATDS on which two science mistresses were co-optees.[65] The committee drew up schemes of work in elementary science, elementary hygiene, cookery and laundry work (appendix 1) but pointed out that "rigid schemes of correlation are inadvisable as tending to hinder the work of both the Science Mistress and the Housecraft Mistress".[66]

For the science teachers a further concern was the sacrifice of scientific method which they believed would occur if domestic science was substituted for science. Ida Freund - not a member of the AST or AAM, but influential as the tutor of many future women science teachers - feared that domestic science would be a diversion from the harder path of physics education. She argued that if domestic science was given a place in the curriculum then "the tendency to take the line of least resistance, to shirk mental effort" would be more accentuated. There would also be no great improvement in the reasoning powers of girls "with the inevitable result of a serious gap in the mental equipment with which we provide our girls for the general business of life and the special business of university study".[67] She further claimed that the diversion to domestic science would deflect from the task of making improvements in the teaching of physics, improvements which many teachers recognised as being required in order to make physics more "real" and "vivid" by using examples from everyday life.[68]

Such views were expressed repeatedly at meetings of the AAM and later the AST. At the annual conference of the AAM in 1909, for example, Miss Wood of Leeds High School read a paper on "a school course of science applied to domestic life",[69] which was based directly on Smithells' ideas. Great interest was shown by the members in her paper, but many speakers "feared lest the difficulty of both imparting and digesting so many facts should lead to a sacrifice of training in scientific method".[70] In 1911 Miss Edith S. Lees, science mistress at Clapham High School who was later to become president of the Association of Women Science Teachers (AWST), the successor to the AST, with Miss K.T. Wallas, represented the AAM on a sub-committee appointed by the London University Extension Board to consider the question of domestic science.[71] The now familiar views came across clearly. Miss Lees stated that

> "while the Association was anxious that nothing should interfere with well established and efficient science courses now carried on in girls' schools, they feared too early specialisation in domestic science, though they wanted closer connection between the school life and the future life of the girl, and they were all agreed that at a certain stage in a girl's career she should have an opportunity of applying her scientific knowledge to home life". (my emphasis)[72]

The following year at the AAM annual general meeting Miss Lees

> "urged that (science teaching) should not be made subsidiary to other subjects. Its aim is to produce clearness of thought, unbiased by personal feeling; it teaches children how to collect facts, to classify and describe them as simply as possible, to sum them up in a so-called law of nature and descriptive formula. Order and continuity are its characteristics. When science was made subservient to 'housecraft' or 'domestic science' this continuity becomes impossible".[73]

Later the AST promoted similar views. For example, in her presidential address to the Association in 1915, Mrs. Marion Bidder laid stress "on the scientific attitude of mind arising from observation and reflection".[74] She believed that "elementary practical physics and chemistry work should lead to the appreciation of scientific method and scientific accuracy". Domestic work should be taught, but "as another craft rather than encourage the attempt to rank such work as science".[75]

The Association of Headmistresses whilst representing a similar range of schools,[76] was more ambiguous in its approach to the question of domestic science. Such ambiguity was in all possibility connected with the role of its members as headmistresses having to have syllabuses suited to all pupils' needs. One member - Lilian Faithfull, Principal of Cheltenham Ladies College and strongly connected to the King's College for Women and the ATDS,[77] believed that courses in home science should be deferred until after the age of sixteen, when a good foundation of science work could be built upon,[78] however after sixteen, she regarded such correlation between science and home science as very important.[79] Similarly Miss F. Gadesden, Headmistress of Blackheath High School, believed that the chief aim of science teaching should be to inculcate scientific method and that courses such as domestic science should follow and be based upon such a training.[80] For some such as Miss Dove from Wycombe Abbey School, a "first grade" school was not the place for domestic instruction at all, but should be postponed until after a girl had finished at school.[81]

An alternative view expressed by Miss Leahy of the Croydon High School for Girls, maintained that

> "there is no longer any need to prove that (a woman) has the mental power and gifts worthy of the best possible training. Therefore the education of girls may now pass into a more enlightened phase, in which the relation of the school training to the future lives of the girls will have due consideration. In this development the application of scientific principles to household arts will follow".[82]

As a corporate body, however, the AHM were cautiously in favour of domestic science as both an alternative science for girls and as a means to reform the science curriculum to make it relate more to life. In 1910, the Executive Committee of the Association, on the invitation of the London University Examination Board, presented "schemes for the teaching of 'Applied Science' in connection with the setting of alternative questions in the matriculation examination".[83] One of these schemes offered suggestions whilst the other four were syllabuses in use in four schools "in which an attempt was made to arrange the science work so as to give scope for the interpretation of the phenomena of everyday life and to form a scientific basis for the actual training in home arts and science which should follow the completion of the regular school course". (My emphasis.)[84]

Herein lay the caution of the AHM. A perusal of these syllabuses shows that, with the exception of one which was clearly influenced by Smithells and which was the syllabus described by Miss Wood in her paper to the AAM in 1909, they were all built on the sciences of physics and chemistry from the age of twelve after a preliminary course in nature study. At some point, most commonly in the fourth year, they "bifurcated" to take account of the different requirements of "academic" and "non-academic" girls. For the latter the stress was on botany and the chemistry of home life. The educational priorities of the Association were obviously towards the "logical methods of practical investigation" which it felt should not be lost in the attempt to make a too definite connection between science and housecraft too early.[85] Such priorities are revealed in a resolution passed at the annual conference which although affirming the importance of giving to all girls a training in domestic subjects, expressed the feeling that such a training should be preceded or accompanied by (in the case of girls leaving at 16) a "consecutive and definite training in scientific method through elementary science". Furthermore, such a training should "supplement and not replace a liberal education as given in public secondary schools for girls".[86]

Thus, with the AAM and the AST, the AHM was not totally committed to the development of domestic science as an alternative to the traditional science courses in girls schools. This was not a rejection by them of the contemporary belief in the need to teach domestic subjects to girls, nor was it a rejection of the idea that domestic subjects teachers needed a sound training in science:[87] it was rather a resistance to the replacement by a more technical course of one which gave a sound intellectual training in the best traditions of a liberal education. In short, it was argued, "the intellectual birthright must not be sold for skill in making puddings".[88] And as Milburn in her thesis on the secondary school mistresses argues, although domestic science opened up new career prospects for women "the needs of girls entering teaching, the civil service and the commercial world" had also to be considered, a recognition of the fact that there were more kinds of women than the domestic.[89] Thus the development of a "domestic science" received no strong support from this influential - at least in terms of girls' schools - section of educational opinion.

Further obstacles to the development of domestic science.

(i) The Board of Education.

The annual regulations for secondary schools published by the Board of Education show that it was very concerned to see housewifery taught in all girls' schools. So impressed was it by the findings of the 1904 Inter-Departmental Committee on Physical Deterioration, that it published the findings of Alice Ravenhills' report on domestic science teaching in the United States before waiting for similar reports to be compiled for other countries.[90] The evidence appears to show, however, that the Board was against the development of domestic science as an alternative to traditional science courses in girls' schools. In 1905, for example, it made the suggestion that in the elementary schools cookery teachers "should avoid any theoretical instruction as to the methods of cooking, or as to the principles of digestion beyond what (was) necessary for a general understanding of the subject".[91] The Board seemed averse to mixing science with other subjects. It is true that in 1909, as noted above, it was encouraging science teachers to relate their work to other subjects in the curriculum such as maths and domestic economy, but at the same time it warned "that the teacher who endeavours to teach two subjects in one may succeed admirably in teaching neither".[92] This aversion was noted by Henry Armstrong, another strong advocate for a more scientific domestic economy, who, addressing the British Association in 1907, said that "science should underlie any improved system of domestic economy", but "regretted that the Board of Education seemed to be adverse to science".[93]

The 1911 Memo considered "the important question whether the combined course, including as it does 'Domestic Science'......has been found a satisfactory substitute for Science of the ordinary type".[94] Although the Memo went to some lengths to establish the reasons in favour for and against a combined course of domestic science, the lasting impression is that the authors were against the idea. Whilst conceding the educational and administrative arguments to a combined course because it avoided difficulties of time table and presented a science which was less academic and more real to girls, the Memo also noted that

> "a teaching of science which leaves out all reference to the phenomena of everyday life is a type of teaching which no-one defends. When it is stated that Science of the ordinary type is academic and unreal what is in fact meant is that much present day science teaching is open to criticism in this particular respect; and it remains to be proved that the substitution of 'Domestic Science' will not introduce other evils worse than those which it is sought to remedy".[95]

It was also noted that "there is grave reason to doubt whether in any schools the problem of correlation has as yet been satisfactorily solved".[96] Interestingly, later in the Memo there was indication of a similar resistance to hygiene being taught as a science rather than as "a separate subject, for the purely practical end of building up good habits".[97]

Another instance of the Board's rigid attitudes was given by Smithells in his evidence to the Consultative Committee on practical work. He complained that the Board's requirements regarding the technical training of students hampered his work. He "despaired" about the ordinary King's Scholar[98] whose "three year course of educational subjects with ordinary science left no time for the specialised work". He argued that, "If, instead of the formal sciences now insisted upon for the ordinary degree, there could be substituted a more suitable range of science, the present amount of time would probably be quite sufficient".[99]

Perhaps the most clear indication of the Board's attitude towards the combination of science and domestic subjects and its distance from the thinking of such people as Smithells and Armstrong is shown in their "Suggestions for the Teaching of Elementary Science" published in 1915.

In consideration of domestic economy for boys, the Board thought that it should be taught "mainly as practical work; only a little science is needed", and examples were given "of how cause and effect can be demonstrated for practical purposes without any instruction in scientific theory being given".[100]

The Board's antipathy towards domestic science was clearly connected with the social anxieties discussed earlier. Concerned that future housewives and mothers should be efficient and practical, and that all girls, whatever their intended futures should receive an education to ensure this,[101] the hybrid "domestic science" could only detract from imparting the required practical skills. Being the arm of the state which had some control over this, it is suggested that the Board of Education was not willing to encourage the development of a combined course of domestic science as an alternative science course for girls.

(ii) Examinations.

Another factor involved in the failure of domestic science to establish itself as an alternative science course for girls was examinations. At this time the whole question of school examinations was the subject of educational debate. Contemporary with the "Interim Memorandum on the Teaching of Housecraft", was the publication of the report of the Consultative Committee on "Examinations in Secondary Schools". At the time of publication there was a great multiplicity of examinations with little co-operation between the various examining bodies and no uniformity between the exams. Each university, profession and occupation held its own examinations so it could mean that some schools were preparing pupils for as many as twenty-two different external examinations.[102] Unsurprisingly this was considered to have a restricting effect on the curriculum of secondary schools.[103]

The headmistresses had shown a great dislike towards state regulations and an examination dominated education both because of their fear of stereotyping, which they considered to restrict their own freedom, and also because they did not think examinations were always the best way of judging a pupil. In 1909 the AHM passed a resolution disapproving of "external examinations for girls under 16 years of age" and which invited "all members of the Association to co-operate in discouraging pupils to enter them".[104] The AAM passed a similar resolution in the following year.[105] The rationale for such a resolution is indicated by Sarah Burstall in her belief that examinations had done harm to children and harm to teachers because they gave them no freedom.[106] Sophie Bryant was also opposed to them because they led to discontinuity and the search by teacher and pupil for the easiest route to pass.[107]

In domestic science, at the time of publication of the report on secondary school examinations in 1911, there were only three examinations, the Oxford Senior Local, the Northern Universities Joint Matriculation Board Housecraft Certificate, and the optional subject of domestic science in the Senior School Certificate.[108] The Northern Universities Joint Matriculation Board included domestic science in group C of its Senior School Certificate Examination in 1910, and in 1911 introduced an examination for a certificate in housecraft. Part one consisted of English composition, history, geography, arithmetic with practical applications to household and business affairs, French or German and elementary science with reference to "common things". Part two comprised elementary science, if it had not been taken in part one, cookery and two of either housewifery, laundry, needlework, drawing and elementary biology.[109] In the academic year 1911-1912 the University of Oxford Senior Examination Board agreed to include domestic science as an alternative science for girls (appendix 2). This however was short-lived. Only thirty-four candidates entered the examination and the subject was dropped in the following academic year.[110] The AHM met these examinations with regret, feeling as it did that "elementary science and art should be inspected rather than examined" and "stereotyped syllabuses are a hindrance rather than a help to the best training and its development".[111]

Given such antipathy to examinations on the part of the female school teaching profession, the overcrowded time table, and the need to coach university girls for their matriculation examinations, an examination in domestic science could not have been a priority. Furthermore, with the Board's proposals, circulated in 1914,[112] to replace the existing examinations in secondary schools with a first and a second school examination, domestic science found itself in a much relegated position, hardly concordant with the aim to make it an alternative science course. The first school examination was intended "to correspond very closely in its scope to the present school certificate examination of the English Universities", and was "based on the general conception of the secondary school course up to this stage which underlies the Board's Regulations..."[113] It was, therefore, proposed that "the subjects for examination will be treated as falling into three main groups, i) English subjects, ii) languages, iii) science and mathematics".[114] Subjects such as music, drawing, manual work and housecraft constituted a fourth group which the Board felt should be inspected rather than examined, not least because of their relatively recent take-up in schools. It did, however, make the proviso that facilities would be given to examining boards offering exams in this subject.[115]

The difference in status of this fourth group from the other three was one of the contentious issues around the Board's proposals and was mentioned in its circular of December 1915 as one of the points upon which interest had been "specially concentrated".[116] In this circular the Board agreed that such subjects could be included in the scheme on an experimental basis. However, because of the war the Board could not put its proposals into action until the formation of the Secondary Schools Examination Council in August 1917.[117] In its circular of June 1917, very little had altered from its statement in 1914 except that it was agreed that "provision should be made for experiments directed to bringing subjects such as Music, Drawing and Manual Instruction within the scope of the exam and for enabling them to count under suitable conditions towards the attainment of a certificate".[118] This was an obvious problem for a subject such as domestic science which did not neatly fit either in group three or group four. By its very nature it was attempting to cross academic boundaries which the Board was rigidly reaffirming in the group system of the First School Examination.

Such a reaffirmation of an academic curriculum, although criticised by the National Union of Teachers and the AHM, was welcomed by the AAM. Both in 1915 and in 1918 it passed resolutions reflecting its academic concerns and its conception of science education as an intellectual training and discipline. Groups one to three were considered most important by the Association and it believed that subjects from group four should not be allowed as an alternative to any of these;[119] all students were to at least satisfy examiners in their science work even if they did not offer a science in the examination.[120] Anxious that "the elements of Chemistry and Physics should form the basis of scientific training in secondary schools, and that botany should not be the only, or even the main Science taught", a resolution passed at an extraordinary general meeting of the AAM in June 1918 placed botany and the biological sciences in group four with domestic arts.[121]

Thus with the development of a group system of examinations the opportunities for domestic science to develop as a science, rather than as a practical craft, were hindered by its relegation to a group of low-status and non-academic subjects.

Within education very few forces were encouraging the development of a domestic science. The female teaching profession as represented by the AHM and the AAM and the AST were opposed to its intrusion into their hard won liberal, intellectual education. The Board of Education wished to see all girls educated in domestic subjects, but were wary of a subject which had not proved itself either to fulfil that requirement or the Board's own requirement that all secondary school pupils should learn some science. Such opposition and antipathy were reaffirmed in the development of a group system of examinations which made no reference to a domestic science, but placed housecraft or domestic arts in what was regarded as a low-status, non-academic group. Two other factors are worth considering with regard to the failure of domestic science to establish itself as a science, the effect of the 1914-1918 war and the science profession itself.

(iii) The 1914-1918 war.

Given the little internal educational support for domestic science, the effects of the war to some extent sealed its failure. As Sillitoe noted in her history of domestic subjects teaching,

> "Generally speaking the effect of the war was discouraging to these efforts to associate science with the teaching of domestic subjects. War conditions led inevitably to the direct pursuit of utilitarian ends..... And the wider range of occupations that the war opened out to educated women pushed domestic subjects back to their old status in the curriculum of secondary schools".[122]

As it was, science work in girls' schools suffered during the war because of the reduction of teaching staff and the lack of apparatus,[123] so conditions were very difficult to allow for curriculum innovations such as domestic science, even if teachers had wanted to introduce such changes.

(iv) The Science Profession.

Freund in her attack on domestic science feared that it would create "a field of work for women exclusively" in which the standard of science was not considered of great importance.[124] Arguably this was what had occured in the United States where domestic science - or home economics - found its place at an early date in the universities and women's colleges. Here, it was claimed by a contemporary advocate of the subject, Alice Ravenhill, that it enjoyed a parity of esteem with other sciences,[125] however, a more recent interpretation argues that support for domestic science was forthcoming because it channeled newly qualified women scientists into "certain 'appropriate' callings" which did not threaten men directly.[126] The field of home economics in the States by the early twentieth century offered such good career prospects that "many persons (even women scientists in other fields) urged ambitious young women interested in science to head for home economics".[127] No such phenomenon occurred in England. Only two university courses in domestic science were established between 1908 and 1927. The first, developed at King's College for Women (later known as King's College for Household and Social Science), attracted widespread interest and financial support.[128] The institution of the course in 1908, followed by a diploma in 1918 and a Bachelor of Science degree course in household and social science in 1920, was the result of a long campaign by Alice Ravenhill to achieve "a London University course in Household Economics".[129] Her allies in this campaign included Arthur Smithells, who had experimented with classes in domestic science for science teachers and had provided appropriate courses and facilities for experimental work in domestic science for students training to be teachers of domestic subjects at the University of Leeds;[130] Lady Rücker and Sir Arthur Rücker, principal of London University, and Maude Taylor, "a leading authority on domestic science education who had long cherished the hope of more scientific training in this field".[131] Gradually they also won over to their cause Professor Dendy F.R.S., Professor of Zoology, King's College, and Professor of Chemistry, Herbert Jackson, F.R.S., who from the first had been "moderately sympathetic", but whose later cordiality was explained by his "warm friendship" with Smithells.[132]

In many ways this university course in household and social science achieved professional status for "women's sphere". This had been keenly advocated by some prominent champions of women's education in the nineteenth century.[133] By 1917 for example, graduates of King's College for Women, were following diverse careers, but they all tended to be careers which reflected women's domestic role. Thus as well as teachers, among the graduates there was an inspector of canteens, a food supervisor, a canteen manager, a housekeeper and a welfare supervisor.[134] Only one graduate of this year appeared not to conform to this pattern, working as a chemist with the Ministry of Munitions.[135]

Significantly, support for this degree course and the later degree course established at Bristol University in 1927[136] generally came from outside the scientific community. The science profession, with noted individual exceptions took little interest in the subject. Several reasons can account for this, not least the fact that the teaching profession offered ample opportunities for women science graduates, with the result that they barely represented a threat to the predominantly male scientific establishment.[137] A further factor which could account for this lack of interest was that the sciences which informed domestic science, such as bacteriology and nutrition were at this time undeveloped areas of scientific inquiry.[138] Thus contrary to Freund's fears, although certain individuals amongst the scientific profession would have welcomed "women's work" in science, the circumstances and the structure of the scientific community did not foster the development of domestic science. In its general failure to "take-off" as a university subject domestic science had no academic power house; it was not widely blessed with professional status nor university standard. The courses developed at the universities suffered from the traditional prejudices against multi-disciplinary and applied work.[139]

The failure of domestic science to become established in girls' secondary education.

Although the link between domestic subjects and science was regarded as important in the early years of the twentieth century, very little educational or scientific opinion endorsed the development of domestic science as an alternative science for girls. By the end of the 1914-1918 war discussion of domestic science in the educational press was barely alive.[140] An article in the "Journal of Education" in 1923 on "The Teaching of Domestic Science in Secondary Schools" advocated its inclusion in the school curriculum on practical grounds alone and made no mention of science.[141] Indeed it appeared that by this time the assumption of the desirable link between science and domestic subjects for girls was no longer tenable. The National Council for Domestic Studies,[141] for example, on the suggestion that some teachers advocated the domestic setting as the correct way to present science to girls, could only commit itself to a reserved "<u>if</u> this is a sound doctrine then it is a strong argument for the inclusion of domestic subjects in the girls' curriculum".[143] Such a statement suggests that all the arguments for and against domestic science rehearsed ten years previously had been forgotten. This is ironic when, at this time within science education, opinion was turning away from preoccupation with the process of science and method, to a concern with its content. The Thompson Committee, reporting in 1918, recommended "that more attention should be directed to those aspects of the science which bear directly on the objects and experience of everyday life".[144] In the same report a long paragraph detailed how science education could be made to bear more closely upon the interests of boys. Domestic science courses were dismissed as having "no claim to the name of science at all",[145] but no mention was made of the schemes which had been outlined a decade earlier which sought to relate science more closely to the supposed "natural" interests of girls. Yet this had been a chief aim of Arthur Smithells, whose call for a domestic science was both an explicit call for the reform of a science curriculum which, bound by tradition and "hampered by precedent", was formal and academic, "absolutely detached....from the concerns of the household and of common life"[146] and an attempt to ensure that all girls were efficiently educated in the management of the home and the care of children.

It is clearly the case that the aim for a domestic science which would replace the traditional science course in girls' schools never succeeded beyond a few isolated attempts, although the teaching of domestic <u>subjects</u> has retained a firm place in the education of girls. It is also the case that where domestic science was attempted it failed. In 1917, for example, the British Association reported that although "domestic science and hygiene are frequently introduced into girls' schools with the object of effecting a link between science and the experience of everyday life", these schools were succeeding in neither aim of giving a scientific or a domestic training.[147] As this report also showed, the girls' public schools and the newer municipal secondary schools still operated along the lines that had been developed in the latter decades of the nineteenth century. Pupils were divided into the academic and the non-academic and it was only for the latter that sciences which had a bearing on domestic life, such as hygiene and physiology took precedence over standard courses in physics and chemistry. This division within secondary education and indeed between the elementary and secondary education systems, was keenly supported by the female teaching profession.[148] But even for non-academic pupils, the development of domestic science courses was hampered by the obvious confusion over what they intended - to teach science or to teach housecraft; to teach both at the same time; or to teach something completely different bearing on both subjects? Secondary education at this time was not orientated towards practical ends. The successive education codes following the 1902 Education Act were built on the notion of a balanced, liberal education. Domestic science which both attempted to cross subject boundaries and which had a high degree of applicability was undoubtedly tainted with a utilitarianism associated with the type of education developed in the public elementary schools.

Thus, domestic science failed to become established as an alternative science subject in the girls' secondary school curriculum. As a form of technical education it continued to be a strong factor in girls' education in the elementary and post elementary education systems up to and beyond the 1944 Education Act.[149]

The attempt by Smithells and those who supported him, to reform girls' science education may be viewed with some sympathy today. As noted in chapter four, the pioneers of women's education in the girls' public schools took on the science curriculum they did more because it was the current standard by which achievement in science was measured rather than because of any strong belief that it was the best way to teach science. However, the women science teachers in the early twentieth century believed, as had their predecessors, that a different science education for girls would be regarded as an inferior science education. Furthermore, an alternative science for girls based on domestic examples was evidently bound up with particular assumptions about women's place and role in society. The advocates of domestic science may have been correct in envisaging domestic science with its examples from "real life" as a good way to teach science to girls, but the fear expressed then was that such a science education did not take girls beyond the domestic sphere.[150] A further important point to note is that domestic science was aimed at one sex only and deflected attention away from the need to reform the mainstream science curriculum and to make it relevant and applicable to all students' lives.

Thus, a "domestic science" could not be accepted by women science teachers or many headmistresses because it intended to create a separate school science for girls. This had explicit consequences for the future of those girls who would go to university - especially in view of the universities' resistance to reform. To accept such a science meant acquiescing to the "separate but equal" dictum which had been successfully resisted by an earlier generation of women educationalists. As in the late nineteenth century the dilemma was still present between taking the same courses as boys - and thus maintaining all the traditions of science education which had been developed in a male educational system, or making science more relevant, which at that time meant linking girls interests to naturalistic assumptions about their future role. In essence it was the continuing dilemma between the demands of "high" science and the desire for a science education for all. Women's position in science and in education at the time was not strong enough to question either this dichotomy, or the validity of the concept of "high" or "academic" science. In consequence, by the end of the 1920's, the science education of girls was in much the same position as at the end of the nineteenth century - physics and chemistry for the "bright" minority, botany, biology and domestic economy/subjects/science for the rest.

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60. Minutes of the Executive Committee of the ATDS, October 30th, 1909.
61. The Board of Education's 1911 Memo gave instances of science teachers teaching domestic economy. In the 1913 report on practical work, reference

is made to an address by Smithells on the subject of domestic science to girls' secondary school governors, mistresses and masters, "In a discussion which followed the address the masters on the whole welcomed the proposal to introduce more of the domestic idea into science work for girls, while the mistresses received it with some caution". In the same report it was noted that Smithells "did not see why for the sake of economy and probably efficiency the Domestic Economy teacher should not also teach science. But whenever the suggestion was made that the Science teacher should equip herself to teach the Domestic Arts, teachers at once questioned the possibility of her being able to acquire the necessary efficiency". Board of Education, 1913, op.cit., p.183.

62. Domestic subjects teachers did not have the same standing on the school staff as did science teachers, for example they did not have charge of forms. See Galiland, M., "Home Arts", in, Burstall and Douglas, op.cit., pp.153-165, (p.159).

63. Martin-Leake, F., "Teaching Natural Science in High Schools for Girls", Journal of Education, vol.33, June 1911, p.392.

64. ibid.

65. ATDS Year Book, 1911, p.22.

66. The relationship of the ATDS to the rest of the female teaching profession and its influence deserves fuller investigation. As an Association it was evidently very interested in the question of domestic science. Smithells chaired the Association's science committee (on which Sara Burstall, Ida Freund, W. Mayhouse-Heller, Professor Jackson, Mrs. Pillow and John Wilson, amongst others, also sat) which, in 1912, considered, "1. Scientific problems with which teachers of domestic subjects are often confronted in their practical work, 2. general education and pedagogical questions arising out of the present state of the teaching of domestic subjects, and, 3. the teaching of science in training schools" (see Sillitoe, op.cit., p.258, and ATDS Year Book, 1912, p.9). Further investigations of how the Association itself defined domestic science, the alliances it made, the sub-groups within the Association etc., would no doubt throw greater light on the whole question of "Science or domestic science". Lack of space and information does not permit this here.

67. Freund, op.cit., pp.158-159.

68. For example, Miss Rose Stern of North London Collegiate School believed "that every good teacher in science in a girls' school should look for examples for experiments from substances which are known to the pupils, for example there is no reason why washing soda should not

be used instead of another carbonate, and Epsom salts as a type of sulphate", Stern, op.cit., p.461.

69. "Association of Assistant Mistresses, Annual Conference", Journal of Education, vol.31, Feb. 1909, p.150.
70. ibid.
71. Editorial note, Journal of Education, vol.33, Jan. 1911, p.18. This sub-committee had the task of considering a syllabus in domestic science approved by the Surrey Education Committee in 1910 for inclusion as an alternative subject in the London University Junior School Examination. It was hoped that the full course might be accepted by the London University as satisfying requirements for the Leaving Examination (Matriculation standard). The first year syllabus included physical measurement, heat, expansion, contraction, clothing, perspiration and personal cleanliness, melting, boiling and the elements of cookery. The second year included air, ventilation, water and washing. The third year included the care of the body, digestion, excretion, foods and drink. The fourth year dealt with the chemistry of daily life, the dwelling house, care of the sick, infectious diseases and invalid cookery. The fifth year dealt with elementary bacteriology, air, water, milk and dust and general elementary biology or first aid. (Journal of Education, vol.32, Oct. 1910, p.656). The Junior Stage was approved provisionally by the sub-committee which allowed it to be taken as an optional subject in July 1911.
72. "Association of Assistant Mistresses", Journal of Education, vol.33, Feb. 1911, p.140.
73. "Association of Assistant Mistresses - Annual General Meeting", Journal of Education, vol.34, Feb. 1912, pp.146-147.
74. "Science note", Journal of Education, vol.37, Feb. 1915, p.85.
75. ibid.
76. See Glenday, N. and Price, M., Reluctant Revolutionaries - A Century of Headmistresses, 1874-1974, Pitman Publishing, 1974.
77. Lilian Faithfull was vice principal of King's College Women's Department from 1894-1907. She later served on the executive committee of the King's College for Women Home Science Department. She also sat on the science sub-committee of the ATDS. (Queen Elizabeth College papers; ATDS Year Book, 1912, op.cit.)
78. Faithfull, L.M., "Science in Girls' Schools", School World, vol.14, Dec. 1912, p.452.
79. Faithfull, L.M., Evidence to the Consultative Committee on Practical Work, Board of Education, 1913, op.cit, p.307.

80. Gadesden, F., "Science in Girls' Schools", School World, vol.14, Dec. 1912, p.454.
81. Dove, J.F., Evidence to the Consultative Committee on Practical Work, Board of Education, 1913, op.cit., p.307.
82. Leahy, M., "Science in Girls' Schools", School World, vol.14, Dec. 1912, p.455.
83. AHM, Annual Report, 1911, p.18.
84. ibid., these science courses are reproduced in appendix B of Milburn, op.cit.
85. Milburn, op.cit., p.242.
86. "Association of Head Mistresses - Annual Conference", Journal of Education, vol. 34, July 1913, p.479.
87. Clapham High School, for example, ran a three year course for training teachers of housecraft in secondary schools. For students with science qualifications the course was two years. See, Board of Education, 1911, op.cit., p.41.
88. Quoted in Milburn, op.cit., p.243.
89. ibid., p.247.
90. Dyhouse, op.cit., p.24.
91. Quoted in ibid.
92. Board of Education, Annual Report, 1909-1910, p.75.
93. "British Association for the Advancement of Science", Journal of Education, vol.29, Sept. 1907, p.649.
94. Board of Education, 1911, op.cit., p.27.
95. ibid.
96. ibid.
97. ibid., p.137.
98. King's Scholars were pupil teachers who had won a scholarship to a training college.
99. Smithells' evidence to Consultative Committee on Practical Work, Board of Education, 1913, op.cit., p.289.
100. "Science note", Journal of Education, vol.37, July 1915, p.393.
101. In a circular, the Board noted "those domestic subjects which cannot properly be omitted from the education of girls, even of those, who, from choice or necessity seek to put themselves in a position of economic independence". Board of Education Circular 826, Memorandum on teaching and organisation in secondary schools, HMSO., 1913, p.15.
102. Board of Education, Report of the Consultative Committee on Examinations in Secondary Schools, H.M.S.O., 1911, pp.29-69.

103. Banks, op.cit., p.83.
104. Board of Education, Examinations in Secondary Schools, op.cit., p.58.
105. ibid.
106. Evidence of Sarah Burstall to ibid., p.533.
107. Evidence of Sophie Bryant to ibid, p.528.
108. ibid., pp.213-303.
109. ibid., pp.212-215.
110. Board of Education, 1913, op.cit., p.73. The examiners' report stated that the candidate's work "was very fair on the whole : some had not much grip of the fundamental points in elementary science on which their answers should have been based, but the majority answered their questions much more intelligently than candidates who had not gone through an experimental course would have done". Oxford Local Examination's Board, Examiners' Reports for 1912, pp.24-25.
111. "Association of Head Mistresses - Annual Conference", Journal of Education, vol.34, July 1911, pp.454-456.
112. Board of Education, Circular 849. Examinations in Secondary Schools - Proposals of the Board of Education for Examinations. H.M.S.O., 1914.
113. ibid., p.2.
114. ibid.
115. ibid.
116. Board of Education, Circular 933, Examination of Secondary Schools, H.M.S.O., 1915, p.1.
117. Board of Education, Circular 966, Examination of Secondary Schools, H.M.S.O., 1917.
118. Board of Education, Circular 1002, Scheme for the better organisation of examinations in secondary schools, H.M.S.O., 1917, p.1.
119. Banks, op.cit., p.86.
120. AAM Annual General Meeting, Minute Book of the AAM, 1915.
121. "Extraordinary General Meeting of the AAM, 22 June 1918", AAM London Branch Report, 1918.
122. Sillitoe, op.cit., pp.181-182.
123. "Science in Girls' Schools", Journal of Education, vol.38, Jan. 1916, p.16.
124. Freund, op.cit., p.288.
125. Ravenhill, A., "Domestic Science and the Domestic Art", Journal of Education, vol.29, Nov. 1907, p.775.
126. Rossiter, M., "Women's work in science, 1880-1910", ISIS, vol.71, no.258, 1980, p.383; see also Ehrenreich, B. and English, D., For Her Own Good - 150 Years of the Experts' Advice to Women, Pluto

1979, pp.136-14.

127. Rossiter, op.cit., p.396.

128. For an account of the development of King's College for Household and Social Science, see Oakeley, H., "King's College for Women", Appendix A to Hearnshaw, F.J.C., The Centenary History of King's College, London, Harrap and Co., 1929, pp.489-509.

129. Ravenhill, A., The Memoirs of an Educational Pioneer, Dent and Sons, Canada, 1951, p.136.

130. Flintham, op.cit., p.170.

131. Oakeley, op.cit., p.503.

132. Ravenhill, 1951, op.cit., p.139.

133. See chapter four for a discussion of this in relation to the "separatist" strand of feminist thinking.

134. Report of the Dean, King's College for Household and Social Science, for the session 1917-1918, Queen Elizabeth College papers.

135. ibid.

136. "A course for the ordinary degree of Bachelor of Science applying to candidates specializing in domestic science has been approved by the Faculty of Science of the Bristol University in response to suggestions from the Gloucester College", Sillitoe, op.cit., p.207.

137. See, Cardwell, D.S.L., The Organisation of Science in England, Heinemann, 1972.

138. See Ravenhill, 1951, op.cit., p.137.

139. See Freund, op.cit., p.280.

140. In the Journal of Education articles on domestic science peaked in 1911 when there were ten mentions of the subject. In 1917 there were three mentions, in 1920, none.

141. Davis, J.D., "The Teaching of Domestic Science in Secondary Schools", Journal of Education and School World, vol.55, Nov. 1923, pp.725-727.

142. This was formed in 1917 by the merger of the National Union for the Technical Education of Women in the Domestic Sciences with representatives from universities, training schools, associations of teachers of domestic science and others. Journal of Education, vol.40, Dec. 1917, p.737.

143. Editorial Comment, Journal of Education and School World, vol.55, Dec. 1923, p.815; similarly, in the Hadow Report of 1923, it was noted that, "a few witnesses advocated the correlation of the 'physical sciences' with 'domestic science', but there is some evidence to show that the

practice of teaching physics and chemistry with a strong domestic bias has proved a failure, and many schools that experimented with the plan have now abandoned it. One witness who had formerly approved of the practice now considered that, 'this method tended to deprive the science teaching of its intellectual value by destroying its sequence'". Board of Education, 1923, op.cit., p.71.

144. The Position of Natural Science in the Educational System of Great Britain, H.M.S.O., 1918, p.75.

145. ibid., p.68.

146. Smithells, 1906, op.cit., p.782.

147. "Science in Secondary Schools", BAR, 1917, p.141.

148. For example, Jessie White wrote in the Journal of Education, "I hope we shall recognise more fully difference of type in girls' schools and give up running the lower middle class girls' schools on the high school plan, as though the only girl who really mattered are the few who go to university". Journal of Education, vol.36, Oct. 1914, p.698.

149. Domestic science neatly fell in with the post-Hadow (1926) trend of linking curricula for "less academic" pupils to their "natural interests". For girls such interests were assumed to be related to a domestic role. These assumptions were incorporated into the Spens and Norwood reports. More recently still the suggestion has been made that domestic science - or home economics - should be considered a branch of Craft, Design and Technology. (See Finch, I., "Home Economics as a branch of C.D.T.". T.E.S., June 10 1983).

150. A similar fear exists today, see Grant, M., "Home Economics: Still tied to the sink", T.E.S., June 24, 1983, p.20.

6. Science for girls - the work of the Association of (Women) Science Teachers.

Introduction.

The preceding chapter concluded that for secondary school girls a "domestic science" failed to become an alternative to the science curriculum as traditionally defined. It was argued that one of the voices in opposition to the establishment of domestic science was the professional association of women science teachers - the Association of (Women) Science Teachers[1] - who, whilst not opposed to the teaching of domestic subjects or housecraft as such, feared that the replacement of traditional courses of physics and chemistry by domestic science would downgrade the intellectual advantages of the study of science, disrupt its logical sequence and have adverse consequences for those girls hoping to specialise in science or medicine at university.

It is intended in this chapter to investigate the work of this Association further. Principally I shall be asking what significance did the existence of the Association have for the development of science education for girls and science education in general? What kind of science did the Association want in schools and how far was it in a position to influence curriculum development? Relatedly I shall be asking if an examination of the work of the Association can tell anything about the hypothesised "process of differentiation" and about girls' exclusion from science because of male defined concerns and priorities of science.

As a teacher association the AWST was unique in that unlike other contemporary subject teaching associations it was a women's rather than a mixed association.[2] As an exclusively women's association with members drawn largely from the girls schools, it was in a position to develop its own ideas about science curricula and syllabuses for girls according to its perceptions about the requirements of girls' education.

Whilst the promotion of science teaching was naturally of interest to the Association,[3] the initial impetus for its formation came from the wish as a corporate body of women science teachers to "be prepared to take a prominent part in the planning of the new science teaching".[4]

Since the general concerns over "physical deterioration" in the early years of the century followed by fears generated in the 1914-1918 war over the "neglect of science", it was not questioned that science should be taught to girls, at least in the rhetoric of the educational authorities.[5] As one major report on science teaching, published in 1918, stated:

> "we feel that there is a need for the fuller realisation than has so far existed of the importance of science in the secondary education of girls. Every young mind, whether of boy or girl, should be led to appreciate the wide field of interest opened out by the study of Natural Science and should be trained to understand and apply the methods of scientific reasoning and investigation".[6]

This being so, the concerns of the Association were more to do with the possibilities for a good science education being present in every school and, as importantly, the type and extent of that education. How then did it perceive science education for girls? Was the Association seeking a different science curriculum for girls suitable for what was assumed to be the domestic function of women? Or, was it by contrast continuing the battle of the "uncompromising" group of women educational pioneers by demanding an equal education in science and an equal educational opportunity for science education for girls? Or were both these strands - and others - in evidence in the Association? What were its values and ideals of science education and how were these translated into practice?

The Membership.

The Association of Science Teachers was formed in 1912, developing out of a branch of the Science Section of the London Branch of the Assistant Mistresses Association. This development was felt necessary because:

> "At the present time the science teaching in schools was passing through a critical period and that for the present at any rate it was useful for science teachers to band themselves together as a corporate whole and not to have their influence weakened by votes of members who are not and have not been engaged in science teaching".[7]

Whilst the Association was open to all science teachers, past or present in secondary schools, and lecturers in science at colleges, and from 1916 to science teachers in any type of school, in effect the Association was, with a few exceptions, a women's association. In 1922, under pressure from the Science Masters Association (SMA) - formerly the Association of Public School Science Masters - the Association changed its name to the Association of Women Science Teachers.[8]

It is of relevance to investigate who made up the membership of the Association and what influences were brought to bear upon it. Initially the Association was numerically small, having only 130 members in 1915, compared with, for example, the 1,315 members of the Association of Teachers of Domestic Subjects, or the 1,140 members of the Modern Language Association for the same date. Even by 1921, when it was well established, its membership was only 360.[9] However, it is not certain how far this indicates that the AST was unrepresentative of its profession, or whether it actually reflected the lack of women science teachers at this time - a lack that the AST, among other things,[10] was concerned to remedy.

The Executive Committee of the Association, in 1912,

> "was characterised by membership from schools which had a strong commitment to the intellectual education of girls. In terms of subject allegiances the physical sciences were at least as strongly represented as the biological ones. At this stage the committee did not include a member from one of the new municipal or county grammar schools for girls. Acquaintance through previously existing networks, notably the AAM and possibly the women's colleges at Cambridge...was a significant determinant of the committee's composition".[11]

Although no membership list is available for these early years of the Association, it is possible to surmise that the Executive Committee reflected the institutional base of the membership as a whole. This can be concluded not only from examination of the structure of the later membership, but also from the focus of the Association's early work - the girls' secondary schools. In 1918, for example, at a general meeting, while it was suggested by the Secretary, Miss Florence Storr,[12] that the Association ought to know what science work was being done in elementary schools and "to suggest how the work might be improved" and also "that the Association ought to be in a position to make definite suggestions as to the curriculum in the proposed new continuation schools", lack of time prevented the matter being discussed or the formation of a sub-committee.[13] It was only in the 1930s, with the gradual widening of post-primary education, that the Association began to focus on post-primary education in general and not just on the secondary schools.

In spite of the openness of its membership regulations, throughout its history the AWST remained an association dominated not only by members from the secondary schools as opposed to elementary schools or higher education, but also, more specifically from the secondary girls' grammar schools.[14]

Table six shows that as secondary and higher education expanded and diversified so did the membership of the AWST although the girls' secondary grammar schools were always strongly represented. This is even more marked when an examination is made of the Executive Committee for the same years (table seven). Not only did members from the girls' secondary schools dominate the committee, but the schools from which they came were principally schools which had developed in the traditions of the high schools or endowed schools of the late nineteenth century, such as the North London Collegiate School, the Manchester High School and the Grey Coat Hospital, Westminster. For each of the three years examined, the North London Collegiate School was represented on the Committee, as was Manchester High School in 1949. Four members of the Committee in 1949 were later to become Presidents of the Association and of these four, two were from old high schools,[15] one from the North London Collegiate School[16] and one from a former endowed school which later became a voluntary aided school.[17] Such representation is significant both for the science traditions which these members brought to the Association, the continuity of the traditions, and how they became (or did not become) established in the work of the Association itself. Indeed it will be a matter of interest here to examine how the models of science education discussed in chapter four were developed, if at all by the Association.

Table 6. Membership of the AWST by institution for the years 1926, 1949 and 1962, as a percentage of total membership.*

Institution	1926 n=465	1949 n=1,376	1962 n=1,711
GPDST	6.5	2.1	2.0
Girls sec.gr.	65.6	57.0	54.2
Mixed gr.**	2.6	5.1	2.7
Girls sec.mod.***	-	0.7	0.5
Mixed sec.mod.***	-	0.3	0.3
Girls tech.***	-	0.4	0.6
Mixed tech.***	-	0.07	0.3
Boys gr.	-	0.1	0.2
Pre-nursing school	-	0.4	0.1
Bilateral schl.	-	-	0.2
Comprehensive schl.	-	-	0.2
Tr.Coll/Coll. of Ed.	1.7	3.4	2.3
Tech. Coll.	-	1.0	0.6
University	1.1	0.9	1.2
Coll. of Phys. Ed.	-	-	0.2
D.S.Coll.	-	0.2	0.6
Hospital****	-	0.7	0.2
Polytechnic	-	0.2	0.6
Other	0.2	0.3	0.5
Overseas	-	1.0	3.3
Private Address (Retired ?)	11.4	19.7	24.7
Uncertain	10.9	6.2	4.8

* Prior to the 1944 Education Act all schools were simply divided into elementary and secondary schools. After reorganisation they were renamed grammar, secondary modern and technical schools.

** Owing to lack of precise information this figure is inaccurate. Possibly the figure for girls' grammar schools should be reduced and added to the mixed grammar school column.

*** These were developed generally after 1944.

**** These members would have been nurse tutors. The AWST did a considerable amount of work on science education for pre-nursing and nursing courses, particularly during the second world war and immediately afterwards (see the AWST Pre-Nursing Pamphlets published in 1943 and 1947).

Table 7. Membership of the Executive Committee of the AWST by institution for the years 1926, 1949 and 1962.

Institution	1926	1949	1962
Girls sec.gr.schl.	7	9	9
Maintained gr.	-	4	2
Vol. aided	-	2	3
Independent*	-	3	4
University	2	1	-
Other/Unknown	-	2	2
Total	9	21	20

* In 1926 these categories were not in operation. There was however a distinction made between those schools recognised as efficient and grant aided, and those recognised as efficient, but with no grant. School lists do not distinguish these two categories.

The AWST in context.

i) The social context.

Before turning to an examination of the work of the AWST it is necessary to place the Association in some context. As Dyhouse[18] notes, adequate accounts of curriculum development cannot be given without reference to changing values, ideologies, social and institutional structures. Thus an adequate account of the work of the AWST in the field of curriculum development requires some understanding of the changing ideology of education, the nature of the labour movement and the sexual division of labour, and the changing school system over the period in question. Locating the AWST in this way will also enable a better understanding of the power of women in science education to make influential or significant changes to the science curriculum.

Detailed considerations of the changing nature and context of schooling have been considered elsewhere,[19] especially in relation to the changing ideology of education and the sexual division of labour.[20] It will be enough here to note the main points of these changes.

The greatest difference in schooling between 1912 and 1961 was the institution of free secondary education for all in 1944, replacing the former system whereby the majority of children received their schooling in the state elementary schools up to the age of fourteen, with a largely middle class minority buying secondary education in the various forms of secondary schools. Of the children attending these secondary schools, a small proportion received their education free through provision of a scholarship.[21] The Education Act of 1944 distinguished three types of secondary education based on the tripartite proposals of the Norwood Report[22] (1943) which, like its predecessor the Spens Report[23] (1939), envisaged the organisation of secondary education by children's differing psychological abilities. Thus the Norwood Report argued that children

> "could 'roughly' be divided into three groups on the basis of their aptitudes, not measured ability. Groups of children could be identified as those who 'could take a long view and hold in their minds several ideas at one time', those for whom the 'subtleties of language were too difficult' and those who could only cope with concrete ideas....".[24]

Such a tripartite conception of education fitted neatly with the existing educational framework of grammar school, junior technical school and central or senior elementary school. The latter two were upgraded to the secondary modern schools and the secondary technical schools.

The Act was hailed as bringing in a "new order in English education",[25] but it can be argued that although it provided free and universal secondary education, the Act was legislation which represented no radical break with previous forms of schooling either institutionally or ideologically. Grammar schools were already in existence and the declaration of the upgrading of the junior technical schools and senior elementary schools was not accompanied by a massive rebuilding programme. Only forty per cent of the local education authorities had junior technical schools before 1944,[26] so the secondary technical school remained the least common of the secondary schools. This was particularly significant for girls, for as Banks notes, the Spens committee did not consider it necessary to recommend a technical high school for girls in order to redress the balance between those entering clerical and industrial posts.[27] Similarly, whilst the senior elementary schools were renamed "secondary modern schools" in 1947, it took more than ten years for some of them to be rehoused from their cramped and substandard accommodation.[28] The private sector was largely left independent of state control, and endowed schools in receipt of a direct grant were given one of three options, to enter the local education authority system, to increase the number of local education authority places or to become independent.[29] Thus the provision of secondary education for all was rather owing more to a semantic reform of the word "secondary" than to any radical change in the organisation of education, or the status of knowledge embedded in a particular organisational form. Whilst the three types of school were to enjoy "parity of esteem" - each school it was argued being ideally suited to the needs of a specific type of child assessed individually - such a parity of esteem was in practice impossible "as long as the traditional secondary school curriculum represented the clearest expression of high status knowledge".[30] Since 1902 the traditional, academic curriculum had become the model for secondary education, superior to the more technical, applied and vocational knowledge offered in the various forms of post-primary education.[31]

In contrast to these institutional changes, it has been argued[32] that a persistent feature of schooling for girls over this period was the sex role ideology apparent in educational reports from Hadow (1923)[33] to Newsom (1963)[34] which supported the sexual division of labour by suggesting that the prime responsibility of women was domestic concerns. As Wolpe argues[35] this manifests itself in the curriculum in two ways. Firstly, particular subjects such as domestic science, "through their contents are specifically and overtly related to the adult female role", and secondly, within particular subject areas "the manner in which the discipline is taught contains the 'profoundly unconscious' ideology which emphasises the application of this knowledge to the division of labour between male and female".[36] What had changed over the period in question however was the nineteenth century emphasis on a <u>natural</u> division of interest between boys and girls, to the greater stress on a child-centred approach in the 1920s and 1930s and the consequent division of boys and girls in terms of their <u>special needs</u> and interests. From the time of the Norwood Report (1943) this again changed to a view of girls experiencing common <u>special problems</u> in schools.[37] This latter point is particularly relevant to the discussion of girls' science education, for as the 1956 White Paper on technical education clearly shows, these "problems" were related to the sex-role ideology:

> "A great many girls do not see the point of further education once they have got a job. Their hopes are naturally bent on marriage and they fear perhaps - though there is much experience to prove them wrong - that by aiming at a certificate they may miss a husband".[38]

A third point to note in relation to the changing nature and context of schooling is the fact that secondary education was becoming increasingly co-educational, particularly after 1944. As early as 1923 in the report of the Board of Education's Consultative Committee which looked at the differentiation of curricula for boys and girls, arguments for and against co-education were rehearsed. In the evidence submitted to the committee it was generally the headmasters who were in favour of co-education and the headmistresses who were against it. Not only did women teachers fear loss of promotion and the circumscribed power of being second in command to a headmaster, they also argued that girls themselves would be disadvantaged. One mistress, for example, stated in her evidence to the committee

> "that she had never found a Co-educational school in which the needs of girls received full consideration. The curriculum was arranged for the boys, the school was run in their interests and in general they acted as a depressing element on girls".[39]

This objection to co-education is important to bear in mind in relation to the work of the AWST and in the light of recent debates on co-education and the scientific education of girls.[40]

A final important point to note for this period, is the entry of married women into the teaching profession. Until 1944 married women were often barred from teaching and women already teaching were usually expected to give up their posts on marriage.[41] In consequence, the female teaching profession was filled by women who had the possibility of devoting much of their free time to their careers. The second world war and consequent shortage of teachers was the final push to end the marriage bar. Also, as in the first world war, wider employment opportunities opened to women making teaching less of an attractive proposition. Thus by the 1950s the integrity of the female teaching profession as a profession of women working principally for the education and interests of girls, was being eroded both by the number of women working part-time in order to meet their family responsibilities and by the increase in co-education which pushed women further down the career ladder.

ii) The science education context.

Within science education itself, the years between 1912 and 1963 were ones in which views on science education inevitably altered. Accounts of developments in science education in the twentieth century[42] suggest that the following issues emerged. Firstly, from the middle of the first world war the theme of the "neglect of science" emerged. It was argued that the neglect of science education in school had had profound and disasterous consequences during the war. This theme, after the war and in the 1920s and 1930s was taken up by educational bodies such as the SMA, the BAAS and the Board of Education, and like-minded individuals such as Sir Richard Gregory and Sir Henry Armstrong, in their arguments for science as an essential part of a general education. Secondly, this new emphasis on science education after the first world war brought forward the call for "science for all" or "general science". This notion of general science also was advocated as a means of avoiding the narrowing tendencies of too early specialisation in the secondary schools. Thirdly, in the 1930s, whilst "general science" was still a major issue among science educators, increasing attention was being paid to biology education. The colonial service created a demand for trained biologists, but on a more general level, biology education was regarded as an important aspect of educating the future citizen. Being the link between the natural and human sciences, biology was seen as an eminently suitable study, by some, to raise moral and ethical questions of modern life. Fourthly, much consideration was given in the inter-war years to the relation between science education in the schools and the universities. Lack of uniformity of school examinations meant that there was often considerable overlap of studies, which was considered neither efficient nor pedagogically sound. Fifthly, with the increasing expansion of post-primary education from the late 1920s, the 1930s saw greater attention being paid to the science work in senior schools and science education for the "non-specialist" in the secondary schools. Finally, after the second world war, uppermost in the minds of educators were the issues of post-war reconstruction, the development of science education in the three types of secondary school, the grave shortage of scientists and technologists, including science teachers and the implications this had for science education.

Public statements on science education from diverse educational bodies such as the AWST, the BAAS and the SMA for example, suggest that there was some consensus regarding the main aims and approaches to science education throughout this period. As regards the aims of science teaching, these were consistently promoted as embodying two aspects - the formative and the informative. Science education, it was said, should encourage the use of the intellect, giving a training in a method of thought. Conversely it should also inform children about the world and the place of science in it. Of the approaches to science education there appeared to be at least three which were commonly agreed. It was believed that children should have a thorough grounding in experimental science before the age of fourteen, at which age diversification was encouraged according to the ability, interests and futures of different pupils. However, diversification and specialisation were not to be at the expense of general education. Particularly after the first world war the "mental training" argument for science education declined, overshadowed by arguments for the place of science in a general education because of its cultural and humanistic values.[43] Finally, by the late 1920s it was generally held that science courses should take as their starting point the interest of children in the natural world.

Science for girls - the AWST and curriculum developments.

Whilst the AWST certainly responded to many of the issues outlined above, a close inspection of their work reveals that, for the most part, these were not the central issues which faced them. Rather, in contrast to the themes which have been recorded in the history of science education, those facing the women science teachers were more to do with the social valuation of education for girls, traditional conceptions of what girls should learn and the nature of the girls' schools.

A consistent problem which faced the AWST was the severe lack of time, laboratories, finance, apparatus and teachers in the girls' schools for an adequate science education. Traditionally the girls' high schools only worked in the mornings, which led to severe problems when time-tabling for an over full curriculum - including as it did all the academic subjects as well as the "accomplishments" of the traditional female education. Also, the literary traditions of the girls' schools led both to a lack of time and possibly of commitment on the part of the headmistresses to science education.[44] In 1918, for example, a general meeting of the AST carried a resolution urging upon the Association of Headmistresses (AHM) "the importance of alloting more time to the study of science and of making the study of all branches of physics the basic part of science teaching".[45]

From its early years up to the amalgamation with the SMA, the AWST produced detailed evidence about the lack of facilities in the girls' schools. In the first few years of existence the AST furnished statistics of the situation in the girls' schools to the Thompson Committee (1918), which went on to report that laboratory provision in girls' schools, including those which were state aided, was "less satisfactory" than that of boys' schools and "quite insufficient".[46] The report quoted the Association's figures "showing that out of twenty-eight schools with between two hundred and three hundred pupils, twenty had only one laboratory and that ten out of thirteen larger schools were no better off".[47] This lack of facilities was further exacerbated by a serious shortage of women science teachers,[48] which the AST attributed to "long hours, inadequate salaries, the extra cost of a university course in science and the rapid development of other openings for women qualified in the subject".[49]

By 1934 some improvements had been made and the Association could report to the Board of Education that "girls secondary schools without some laboratory accommodation are now rare, and many of the larger schools are well provided in this respect". It also reported that more time was generally available for the teaching of science, and there was no shortage of qualified teachers.[50] However, there were still major problems and the Association highlighted seven factors which hindered the science work : large classes; inadequate time allowance for science;

inadequate accommodation; lack of assistance in the laboratory; over-emphasis of demonstration at the expense of class experiment; cramping effect of examinations; unsuitable preparation of teachers.[51]

Such problems continued to persist, however, for eight years later, in reply to a Board of Education questionnaire sent by the Committee under Sir Cyril Norwood's chairmanship, an almost identical list of dissatisfactions was sent:

> "1. Too few good teachers of science.
> 2. Lack of appreciation by the Head-Mistresses of the need of time for science mistresses to prepare practical work, and a tendency to put non-science lessons into laboratories, thus further hampering preparation.
> 3. Large classes.
> 5. Lack of laboratory accommodation, inadequate buildings and equipment in some schools.
> 6. Lack of sufficient laboratory assistants".[52]

In addition, the fourth complaint listed was of "the tendency, growing less, but still prevalent, to ignore the cultural aspects of science". Showing some concern for the status of science education in girls' schools, the Association added, "this is sometimes shown by the too great emphasis laid upon the study of languages".[53]

These demonstrations of the inadequacies of facilities for science education in the girls' schools were reinforced by the surveys carried out by the Association on the need for laboratory assistants and matters such as petty cash for science departments.[54]

Even by the 1950s, when widespread concern regarding the shortage of scientists and technologists developed, girls' schools were not the major recipients of new money made available for science education. The Industrial Fund for the Advancement of Science Education was overly concerned with boys' science education and by 1957 only sixty-nine girls' schools received money from this fund compared with over two hundred boys' schools.[55] Interestingly the girls' schools themselves were blamed for this imbalance on the ground that they had made themselves ineligible for aid, "because they have not done enough to help themselves and to show serious intention".[56] In 1961 a questionnaire circulated to girls' grammar schools by the AWST showed that difficulties of finance, staffing and choice of subject still existed, with an average of eight shillings and tenpence (under 45 pence) being spent on equipment for the physical sciences per pupil per year in girls' schools, compared with fifteen shillings and tenpence (just under 80 pence) for boys.[57]

This lack of facilities of every type presented enormous obstacles to efficient science teaching in the girls' schools, obstacles very different from, or minimised in, the boys' schools. Yet, the Association was not concerned merely to replicate what was being achieved in the boys' schools. In general the aims and organisation of girls' schools were different to boys' schools. First and foremost, unlike the vocational leanings of the boys' schools, either towards university and the professions or to industrial and clerical careers, the girls' schools were about education in its broadest sense. This stress on education first and vocation second is clearly evident in correspondence the AHM had with Sir Eustace Percy, President of the Board of Education in the 1920s, over the question of the first examination:

> "From our interview with you it would appear that you favour a system of the institution of a small number of schools with a definitely academic bias and a large number of schools with a practical or aesthetic bias, in short, segregation of the different type of boy and girl mind; while the Headmistresses would wish to see in every school a community consisting of boys and girls of varied abilities and gifts, each with something to contribute to the intellectual and social life of the school".[58]

The girls' schools corresponded much more closely to a "community" than did the boys', with many girls continuing schooling until the age of 18 following a variety of very different courses.[59] The AWST attended to the scientific education of <u>all</u> girls in this way and considered the best way to teach science to girls in relation to the particular institutional arrangements of the girls' schools. As will be discussed later, this allowed for a breadth of approach noticeably lacking in the SMA. However, the comprehensive nature of the girls' schools was not without its problems for the Association. Its members frequently had to confront the difficulty of preparing girls for academic examinations determined by the universities - examinations which required a high degree of specialisation - and yet at the same time maintain a general science education for "the mass of reasonably intelligent girls whose brains are not of the creative order, those who have no great power of mental initiative, but whose intelligence can learn and appreciate a great many of the facts and methods that come within the scope of natural science".[60] Miss M.B. Thomas, president for 1923,[61] made this a theme of her address, pointing out that "it was impracticable under existing conditions to combine preparation for university entrance examinations with the wide and more generalised science instruction which was so generally felt to be desirable".[62] Obviously lack of time, apparatus and teachers only compounded these problems. As secondary education expanded, the women teachers also had to cater for an even wider range of pupils, not so much in terms of ability, but in social background. Increasingly, the girls' schools could no longer assume that their pupils "came from homes which had a certain degree of culture, whose vocabularies were more enlarged than those of the average child".[63]

Curriculum Priorities.

Given these parameters within which the AWST worked, what were its curriculum priorities and why? Were these different from those of the SMA? Did the Association succeed in its aims?

It is only through an investigation of actual syllabuses, critiques of existing syllabuses as well as various resolutions and public statements about its ideals of science education that the interpretation and practical application by the AWST of the broadly agreed aims of science education becomes clear. Between 1915 and 1959 the Association produced at least nine school science syllabuses or critiques of other syllabuses, and it is from these that the following discussion is principally taken.[64]

Perhaps the best expression of the ideals of the Association lay in the Introduction to its Interim Report on Science in Post-Primary Education, published in 1944. In short these ideals embraced the views that a science course should be general, less academic than science courses were found to be, based on social relations and absolutely relevant to "modern interests and applications". The science course should involve some science history and be child-centred rather than subject-centred. Indeed, the course should aim to be in touch "with the normal interests of the boy and the girl". It should aim for a balance between pure and applied science, individual practical work and demonstrations, theory and practice. Subjects relating to "everyday life" should be used throughout the school career. The education should not be restricted to the classroom, but as well as employing aids such as the cine-projector and the wireless, should include visits to workshops and factories and from people working in them for lectures and discussions. Finally,

> "the attempt to achieve the ideals set forth must be accompanied by the development of an experimental and objective attitude to problems, for this is the main bulwark against an attitude of passive acceptance and credulity, the main bridgehead in the fulfilment of our ideals".[65]

This statement was the culmination of years of discussion and practice since the formation of the Association. The last point mentioned, for example, can be found stated as early as 1917 in a resolution passed by a General Meeting. In this it was agreed that science teaching in schools should aim at developing in pupils "the power to observe accurately, to reason logically from observed facts; to frame hypotheses and to test these hypotheses by means of their own experiments".[66] The stress on social relations in the 1944 Report also reflected one aspect of this 1917 resolution, in its statement that science teaching should develop "an appreciation of some of the wider problems with which science deals at present and which can influence modern thoughts and modern activities".[67] Similarly, as early as 1926, Miss C.M. Taylor,[68] in her presidential address noted "our use of an historical approach to science knowledge and our attempts to introduce girls as early as possible to scientific literature....".[69] In 1932, Miss I.M. Drummond[70] stressed the importance of practical work and of the history of science. In an article in the "New Era" in the same year she noted the compromise that science teachers had to make between the two opposing aims of science teaching;

> "one leading us to give breadth of interest, to move forward quickly and to touch on as many and varied topics as possible, the other leading us to dig deeply, to go slowly, to emphasise training in a method of

> thought rather than an acquisition of wide and varied knowledge".[71]

This diversity of aim was also clearly articulated in 1939 at a Special General Meeting held to discuss the Spens Report and the SMA General Science syllabus. At least two ideals of science education emerged in this discussion. One linked it with the main principle of education, which "is surely the search for truth, goodness and beauty, the aim to give the child some Knowledge of God"[72] - an ideal reminiscent of Sophie Bryant's "unity of knowledge". The other placed science firmly in the material world, aware of the limitations of both school and pupil. Thus one member, Miss Rayner, admitted, "I really think that as far as science is concerned, I am only teaching to give a child interest in its general life....I merely want it to go out of the school with an added interest in the circumstances of its life".[73] She went on that the time allowed for science in school "is obviously not sufficient time to give any ideas whatever of scientific method, but I really do not consider that that is necessary for the average girl, or even the girl of good average intelligence who has not a scientific interest".[74]

In short then, the ideals and priorities of the AWST embodied at least five points. Firstly there was always an emphasis on science in context, in its relation to society; secondly, it was believed that science education should have a historical dimension; thirdly, the Association held a total conception of science and its links with other subjects in the curriculum; fourthly, that even the girls going on to specialise in science should not lack humanistic studies and early specialisation was thought particularly abhorrent; finally, it was consistently argued that the child's own interests and experience should always be taken into account.

The institutional reality which the members of the AWST had to confront meant that these ideals could not always be upheld. While the Association argued that science was "among the most important subjects of study in the secondary school, <u>especially</u> from the point of view of the average child who will leave school at the age of 16"[75] (my emphasis) it was forced, for various reasons, to distinguish between what was readily admitted to be a minority of girls above the average who would continue with their study of science at university, and the great majority for whom science education was but one part of their school life.[76]

Science for the "specialist".

In its early years the Association resisted any attempts to undermine what was perceived to be the academic nature of group three of the General School Examination by the inclusion of subjects like biology which could be regarded (although not by the Association itself) as a soft option.[77] What was feared was any altering of standard which could be used as an excuse by others to bar an already difficult path for girls passing from school to university. In this way the AWST was reluctant to support a Miss E. Beard of Bradford Grammar School who wished to approach the university of London to ask that natural history, though not at that time a subject for matriculation, might be accepted as equivalent to physics and chemistry or botany for purposes of exemption from the London matriculation where a "credit" was obtained in the school examination. The Association felt compelled to reply that it was "difficult to press for its introduction when it is known that the substitution of natural history for botany may mean loss of exemption from the London matriculation". This applied to many girls aiming for London degrees in all subjects and not just science subjects or medicine.[78] Thus in spite of opposition to early specialisation, if it wanted girls to continue to university, there was little that the Association could do about the standards and requirements the universities imposed upon the schools. Nor could the clear bias towards boys in examinations such as the Cambridge Higher School Certificate be altered by the Association.[79] An attempt made by the Association to combat this power of the universities over the schools by the formation of a Joint Consultative Council of University and School Science Teachers failed (see later), and the institution of the General Certificate of Education examinations in the 1950s set the final seal to early specialisation in schools.

For the "specialist" then, science education was determined largely by the requirements of external bodies, particularly the universities. The AWST could hope to have little influence on this although it consistently argued for as broad science courses as possible and for non-science courses for the science specialist and vice versa.[80] The role of the AWST as regards the science education of these girls was more one of defending girls' interests in the science examinations than of developing new approaches to science education, although it did try to influence the examination boards.[81]

In terms of differences between boys and girls in science education for those pupils who would specialise in science, it could be concluded that the Association in its early years maintained an "uncompromising" attitude fearing, like Emily Davis, that different meant inferior. This gave way in the 1920s and after to a louder call for the reform of examinations consistent with the Association's ideals of a broader education in science. However, as will be discussed more fully later, the Association was quite powerless to make changes and had to be content with letters of protest or with sitting on science panels of examination boards.

Science for girls.

It was with the science education of the majority of girls up to the age of 14 or 16 that the AWST had the most scope to develop syllabuses, particularly if they were non-examination syllabuses. The main aim throughout was consideration of the best way to teach science to girls of a wide range of aptitudes and interests. It was in this way that syllabuses were produced both for girls considered to be of lower "mental capacity" than the average as well as examination syllabuses for the "ordinary" secondary (grammar) school girl. A study of these syllabuses reveals a consistent set of curriculum priorities.

The first noticeable feature of much of the AWST's criticism of existing syllabuses was the amount of mechanics found in them. On the physics syllabus in 1915 for example, the Association decided that for girls of sixteen the mechanics syllabus of the existing school certificate syllabus was too full.[82] In its criticism of the general science syllabus drawn up by the SMA, it was thought that there should be "considerably less physics", with a reduction chiefly in the amount of mechanics taught; for example "other ways of obtaining velocity ratio and mechanical advantage (year 2), much of the outlines of engines, (year 3), governors, rotary pumps, turbines, calculations on horsepower and efficiency of engines (year 4)".[83] In 1957 it was again stated that the mechanics course in the SMA secondary modern science syllabus was, for girls, unnecessarily full and "that the work may be considerably cut down....and the time saved spent to greater advantage in biological topics".[84] Similar remarks were made about the amount of time devoted to electricity in the SMA syllabuses, with the suggestion that in year 4 of the general science syllabus, the "possibility of measuring voltage by high resistance ammeter, to which three lessons are given, could be cut".[85] Again in 1957 the emphasis on electricity in the syllabus prepared by the SMA was felt to be too much and unnecessary for girls, although the Association stressed that "as a citizen of the modern world, a woman needs to be able to use electrical appliances with a reasonable degree of safety".[86] This point is important. It was not that the AWST felt that the study of mechanics or electricity was unimportant for girls, but as stated in response to the SMA general science syllabus, these subjects were "thought to be better adapted to the needs of boys than of girls".[87] By contrast the syllabuses of the AWST stressed the everyday, practical uses of mechanical and electrical knowledge, with the emphasis on simplicity: "simple phenomena of electric currents....simple practical applications....simple study of electromagnetic induction of the motor and dynamo".[88] The emphasis on practical applications of electricity was a feature of alternative suggestions made by the AWST both in 1915 and 1931, using fuses, electric irons, electric bells, light, telegraph and telephone to illustrate the subject matter.[89]

In its criticisms, the AWST contributed an important corrective to what was perceived to be the male bias of the syllabuses of the SMA and other bodies. In this way the Association made an explicit distinction between science education for girls and for boys based to some extent on an assessment of differences in future occupations. Taking the "needs" of girls as the starting point, the implicit assumption was that given women's position in the labour market and in society generally, detailed excursions into theoretical mechanics or the principle of electricity would serve little future use for most, if not all girls. Far more useful, it was reasoned, to equip them with the understanding and knowledge to comprehend intelligently their everyday world which was increasingly being invaded by technology. This viewpoint is borne out by some correspondence of the Association with the Women's Engineering Society in 1943. In answer to a query, the general secretary of the AWST "was instructed to reply to the Women's Engineering Society that 'girls do not need so much emphasis upon mechanics as normally there are not many engineering posts open to them'".[90]

Another striking feature of the work of the AWST was the emphasis on linking science education to everyday life, either through illustrative examples, or through the history and the social responsibilities of science. In the physics section of the syllabus proposed by the North-West Branch in 1931, for example, the selection of subject matter "had been determined by the direct application of the subject to the girl's immediate surroundings".[91] Such bias is also clearly evident in the syllabus recommendations of the 1944 Interim Report:

> "straight line propagation of light, shadows, eclipses, (searchlight, headlights); expansion and contraction of solids, liquids and gases (regulo-cooker, incubator, fire and frost alarms, heatproof dishes, pneumatic tyres in the sun), preparation and properties of CO_2 and uses (in health salts, baking powders, fire extinguishers, soda water and solid CO_2 used in refrigerators)....".[92]

Science in this syllabus was made to be seen as a human invention. Time was given to the history of science and to the people involved with particular discoveries. This form of syllabus was intended both for younger (11+ - 13+) pupils and for older pupils (13+ - 16+).

In biology, the priorities of the Association were with human biology rather than with too much emphasis on plants and animals. In its criticism of the SMA general science syllabus, observation and study of insects and simple forms of animals and plants were felt to have received too much time allowance to the detriment of "such important subjects as heredity and reproduction".[93] The AWST's own general science syllabus[94] was slanted towards human and animal needs. Very little of the syllabus related to plants and that which did was of an experimental nature. The final topic of the syllabus was "Gradual Evolution of Parental Care".[95] In the 1944 Report, biological knowledge was included in the fifth section on "people". In this there was a thorough treatment of basic physiological information incorporated in what could now be understood as a health education course - nutrition, first aid, energy and exercise, relaxation and rest, elimination of waste, growth and growing up. For girls in the secondary modern schools of the 1950s, the Association suggested that biology and health education could be regarded as a suitable angle of approach to nearly all the science taught, except electricity and parts of the chemistry course.

There are two points which need to be unravelled here. Firstly, the Association's preference for human biology as opposed to animal and plant biology, and secondly, whether the Association thought that, at least for the "less able" girls, biology was the most suitable science.

Taking these points in order, it is quite evident that the Association's preference for human biology links both to its conception of science education as informing about society and its social relations <u>and</u> to its own conceptions of women's future domestic role, (or its perhaps more realistic assessment that this <u>would</u> be the future role for most of their pupils for at least at some time in their lives). Thus, as with the question of mechanics and electricity, the Association wished to equip girls with basic, useful knowledge. A further explanation could lie with the Association's long connection with the Social Biology Council and the Health Education Council.[96] The interest in biology education as part of an education for citizenship in the 1930s could have been an important stimulus to the views of the Association here, but it is likely that this only added further encouragement to courses already to be found in some girls' schools.[97] Finally, by way of explanation, it could be suggested that, as women teachers, the AWST were better able to develop courses much more suited to the requirements of "citizenship", being better able to deal with potentially awkward subjects like "growing up" or "parental care". It could perhaps be argued that the emphasis by the SMA on the study of insects and simple forms of animals and plants, possibly involving dissection and microscopic work rather than human biology is evidence of stereotypic masculine "detachment".

This emphasis on the study of human biology and even parental care does not necessarily suggest that the AWST regarded biology as a "girls'" science.[98] The 1944 Interim Report for example is unambiguously addressed to both girls and boys and whilst the chapter on science for girls in secondary modern schools[99] does stress biology as the approach - presumably because of conceptions about girls' "needs" noted above[100] - this biology course was to be "based on a firm foundation of physics and chemistry, sound in treatment though limited in scope".[101] In other words, girls would receive an education firmly linked to life and its healthy continuance, encompassing all the sciences - physics, chemistry and biology. Certainly, for the AWST the 1957 document is unique in its particular emphasis on biology for girls. Perhaps an explanation here, would look to the authors of the chapter - Miss P.M. Legh and Miss N.M. Whitworth, two older members of the Association,[102] at least one of whom expressed a marked preference for biology.[103] Alternatively, it could perhaps be argued that this stress on biology for girls is evidence of an increasing differentiation between the education of boys and girls at this time covertly through the "hidden curriculum" rather than overtly by sex segregation.

Other notable features of the AWST syllabus recommendations and criticisms are firstly, an emphasis on the links science education had with other subjects in the school curriculum, secondly a positive bias towards qualitative rather than quantitative analysis and finally a sensitivity to the interests and experiences of children as a starting point for science education.

The idea of linking science with other school subjects was certainly not original to the AWST. As is clear from the discussion in chapter five, the notion of "domestic science" emerged from a conception of correlating chemistry and domestic subjects. Whilst the AST had been opposed to the idea of "domestic science", neither it nor the AWST were against greater co-operation between teachers of different subjects in schools. In 1923 Miss M.B. Thomas in her presidential address pointed out that "it was obvious that science and languages, English, etc., could be mutually helpful and that a closer co-operation between the mistresses teaching these subjects would result in advantage to all subjects".[104] Developing this further, Miss Drummond in 1932 gave her view of the relation of science to other subjects in the curriculum. The influence of Sophie Bryant, Drummond's predecessor, is evident here:

> "knowledge should be a whole and it is always a pleasure to be able to break down the watertight compartments

> in which we are too apt to confine it. Colour may be dealt with in the art room and laboratory, with collaboration between the two teachers concerned and with great enhancement of the interest of the subject. Air pressure, precipitation, expansion and contraction with temperature, weather charts, plant products and chemical industries are common ground between science and geography. The history of scientific discovery is one section of the development of human thought and society. By indicating these links and by fostering an overlapping of subjects, wherever this is possible, without interfering with the proper development of the course, an appreciation of the many sidedness of scientific knowledge may be greatly helped; so too, may the appreciation of the place which science fills not only in the practical life, but in the whole thought atmosphere of the day".[105]

These views on correlation were not fully developed beyond recommendations in the 1931 syllabus of the North-West Branch and in the secondary modern scheme outlined above. They were at their most fully developed in the syllabus of 1944, but the links to be made here were rather more <u>within</u> the science curriculum than across the school curriculum as a whole. No doubt as with "domestic science" very real obstacles stood in the way of proper correlation, not least of which was the organisation of the school day and the professional, specialised training of subject teachers.

As regards the emphasis on qualitative rather than quantitative work, as evidenced in 1915, 1931 and 1939, it is only possible to speculate as to reasons. Quantitative analysis requires more apparatus and more time to carry it out than qualitative analysis. In this way the choice of qualitative analysis could have reflected the lack of time and lack of resources which the women science teachers faced. Alternatively, it could have reflected their preference for science related to everyday life, to which qualitative analysis is more suited; or preconceptions held about the general ability of girls to do science - qualitative analysis being less complex than quantitative. Importantly also, qualitative analysis required less mathematical calculation, which might have been an important consideration for the women science teachers given the restricted mathematical education in many girls' schools.[106] Furthermore, once science is "mathematised" it is easier to make it abstract and to de-contextualise it. It was precisely this de-contextualisation to which the AWST were opposed.

As regards the third and final point, whilst the Association was sensitive to the interests and experiences which girls brought into the classroom, it never championed a thorough child-centred approach. It was clearly stated by the AWST that science education should be compatible with "the normal interests and environment of the average citizen".[107] Thus syllabus recommendations were made which stressed the relation of science to the everyday life with which girls would be familiar. This explains the view of the Association in 1944 that the science course should aim to be in touch "with the normal interests of the boy and the girl".[108] This approach informed the Association's criticism of the university examination boards, whose examinations, it was argued, prevented pupils from

> "developing at their own rate and in the time available their powers of observation, experimentation and reading. Instead they must cram facts and practise detailed techniques many of which have little or no significance in their future training and career. The inclusion of topics of everyday interest and importance becomes virtually impossible except at the expense of still more energy and time and merely adds to the strain".[109]

This stress by the AWST on "normal interests" was regarded as an approach to science education, relating it to everyday life. It was not regarded as a curriculum principle which then allowed some children to opt out of science.[110] Throughout its work the AWST insisted on the need for all girls to have a thorough grounding in experimental science and an understanding of scientific method. While the Post-Primary Science Report advocated an integrated approach to science, it did not advocate in any sense a move away from the intellectual demands of science. Throughout its lifetime the Association maintained a firm commitment to the intellectual aspects of studying science, a commitment which represented a strong continuity with the women teachers' nineteenth century predecessors and the high school tradition.

In summary, what I have argued is that the curriculum priorities of the AWST were five-fold. First, the Association wanted to correct what it perceived to be a male bias in the existing and new science syllabuses. In this respect a reduction in the amount of mechanics and electricity was advocated, along with a greater emphasis on their practical applications. In biology education the Association wanted to see the emphasis on human biology and not animal or plant biology. Second, the Association in its own syllabuses stressed the link between science and everyday life, the history of science and the social relations of science. Third, there was some demand for links to be made between the science curriculum and other subjects in the school curriculum. Fourth, the Association stressed qualitative rather than quantitative analysis, and finally, it sought an approach to science education which was sensitive to the needs and experiences of the child. In explanation of these particular priorities I have pointed to the institutional constraints of the girls' schools themselves and the social constraints in terms of expectations of women's role and the sexual division of the labour market. A third possible area of explanation yet to be explored is that the priorities of the AWST reflected in some way a particular "feminine" approach to science education.

Reaching firm conclusions on this point is difficult not least because of stereotypical notions of what it is to be "masculine" or "feminine". Thus, it would be easy to conclude that the AWST advocated a biological approach to the study of science for girls in 1957 <u>because</u> it was an association of women. However, such a conclusion would be repudiated by showing, as I have attempted to do, that the AWST insisted on a thorough grounding in experimental science, with attention to the intellectual issues of method as well as content. That the AWST wanted to correct a male bias it perceived in the SMA curricula does not of itself mean a "feminine" approach, merely a realistic assessment of the future "needs" of girls. If, however, some examination is made of the differing emphases which the AWST and the SMA made in their curricula recommendations, then it is hard to ignore the fact that one was an all-female association and one all male.[111] This is most clearly evident in the contrast between the AWST reports on Post-Primary Science Education (1944-1947)[112] and the IAAM/SMA book, "The Teaching of Science in Secondary Schools" (1947).[113]

The first report of the AWST, published in 1944, approached the question of the study of science with the idea of the "citizen" in mind, and how science education was extremely well-suited to cater for this. The ideals were set out as follows:

"There is need to prepare for life and living, to give an enthusiasm for living positively a good life; there is need to create a bias towards the social responsibilities of man; and there is need for a background of knowledge based on sound scientific principles".[114] (my emphasis)

The perspective of the AWST was thus a social one. In the introduction, science was presented as a part of life, and science education as a way both to understand life and "to attack and solve, to observe, to enquire and to respect the truth" and also to improve life both through a "normal and positive attitude towards personal health", and through "a lasting enjoyment in active pursuit of some not merely evanescent past time". For the AWST science had civic responsibilities:

"It is hoped that the fulfilment of the foregoing aims will result in the creation of a better social responsibility on the part of the individual to the home, to the community and to other forms of life than has hitherto been the case in general".[115]

In contrast the IAAM/SMA document had a far greater emphasis on science education as an end in itself, rather than its social functions:

"Science teaching in a school has a two-fold function to perform. It must give the student a systematic training in careful observation in experiment and in the estimation of the relative value of results. It must provide for all a knowledge of the material world and of the forces of nature. At the same time, for the small proportion of pupils who will later become scientists, it must lay a sound foundation for more advanced work".[116]

Rather than science being a tool of citizenship, a means of reaching the truth, the IAAM/SMA regarded it necessary to teach science in order that "the debt which the community owes to science (could) be known to every citizen". Science in this view was no longer a potentially benign force, but something to revere. Another emphasis in this document absent in that of the AWST was that on the conquest and exploitation of nature by man for his own benefit. It noted, for example, that

"an intelligent understanding of human society is incompatible with ignorance of science since the

> characteristic features of modern civilisation depend on man's conquest of nature by the application of scientific knowledge".[117] (my emphasis)

In contrast to this dominating conception of science proposed by the SMA, and its reified notion of science as something to which civilisation should give grateful thanks, the AWST emphasised the social relations of science and the part it could play in the formation of a better society. The investigation of only two documents gives insubstantial evidence from which to draw firm conclusions, but in view of the work of Gilligan and Keller, noted in chapter one, there is some basis for suggesting a peculiarly feminine approach in the work of the AWST.[118]

How far did the AWST succeed in their aims?

I have argued that the ideals of the AWST were embodied in its reports on Post-Primary Science Education published between 1944 and 1947. These brought together the preceding thirty years of discussion with proposals explicitly geared to the re-organisation of secondary education following the 1944 Education Act.[119] It is from an assessment of the influence of this report that I conclude that, whilst the AWST actively contributed to discussions on science education, whilst they made positive proposals for its reform, and whilst they asserted the interests of girls, they had little profound influence on the direction of science education.

The Post-Primary Report was generally well received. A review in the journal "Nature" reported that "a progressive outlook has produced syllabuses that are less academic than usual, although the experimental and objective attitude to problems is regarded throughout as of paramount importance".[120] Similarly in 1946 a review proclaimed that "the two reports....should be in the hands of all those whose minds are awake to the possibilities of science teaching within the new Education Act".[121] J.A. Lauwerys noted in the "Journal of Education" that the Interim Report was "thoroughly modern in conception and enlightened in outlook. Within this framework science could be taught really well....One hopes that their proposals will quickly bear fruit in practice".[122] Only R. Weatherall, Education Secretary of the British Social Hygiene Council, was somewhat disparaging and patronising in tone, calling the second part of the report "a deserving piece of work", and noting that in spite of its faults of brevity "the AWST should feel encouraged by what has so far been achieved and should empower their subcommittee to continue with their deliberations".[123] However, in spite of this near total acclaim, what was a far-sighted and progressive document was ignored in the ensuing science education policy of the 1950s, taken up as it was with the new G C E examinations and increasing concern over the shortage of scientists and technologists.[124]

The reasons for this all relate to the simple fact that as an association of professional, mostly single women in science, the AWST had little power to wield much influence. The Association had always been aware of its weakness, judging by the wide ranging links it made with other associations from its early days,[125] and their more specific links with other women teachers. In 1918 for example a Scholarship Committee was established with the Headmistresses Association in order to discuss the difficulty of preparing girls for University,[126] and, some years later, the Association established close links with the AAM Science Panel[127] working jointly on projects such as general science.[128]

In 1919 the AST attempted to initiate links between university and school science teachers in order to achieve a dialogue between the two institutions on the science courses in each. Thus was the Consultative Council of University and School Science Teachers established in January 1919 "to discuss the scope and method of the higher work in schools and its relation to the work of the universities".[129] The hopes for this council were not only for dialogue between the universities and the schools, but also to facilitate special courses for school science teachers at the universities so that they could "keep abreast of the various advances made in the various branches of science".[130] It was also hoped that co-operation between school and university science teachers could both mean less specialisation in school work to be followed by higher, more specialised work at the university and rationalisation of school and university science work.

Although never very active nor influential,[131] by the late 1920s the council was floundering. It was reported to have been resuscitated in 1929[132] and met at least once in 1930,[133] but, by 1933 it faced severe problems. The universities did not support the Council - claiming that it could do no useful work, and their withdrawal prompted the withdrawal of the SMA.[134] In consequence the Council ceased to exist at this date.

The fate of the Council indicates at least two things. Firstly the universities were not willing to forgo their power to dictate terms for the school science curriculum to the schools, nor to alter their own syllabuses; and secondly that the SMA appeared unwilling to support an initiative of a women's association which potentially rivalled its own. Shortly after the establishment of the Consultative Council the SMA were jeopardising its chances of success by establishing its own means of communications with the universities. Fearing this, in 1921 the Secretary of the AST "was instructed to write to General Hartley at Oxford to ask him if the proposed committee of university representatives with members of the SMA would not be working on the same lines as the Consultative Council of University and Science Teachers of which he is a member".[135] In 1925, in what amounted to another blow to the Consultative Council, an SMA sub-committee was appointed to consider the matter of the relationship between school and university science teaching, particularly as regarded examinations.[136]

Indeed looking at the relationship between the SMA and the AWST it is difficult to avoid the conclusion that the SMA were at best patronising and at worst obstructive towards the AWST. A good example of this is the formation of the AWST itself. The reason why the formally mixed AST became the women-only AWST was not because of some feminist belief in autonomy, but rather because of a directive from the SMA as a condition for a half-share in the journal, the School Science Review. As a small and financially weak association, the AST could not hope to produce its own journal so it complied with this condition of the SMA. However, the AWST were quite aware that this was an expedient move by the SMA "as they wished to exclude the possibility of a large, mixed association which would rival themselves".[137] Judging by this particular minute it appeared that the AST was prepared to consider the formation of a joint association with the SMA. This was in fact proposed by one member of the SMA, suggesting that a National Science Association be formed, but the idea was rejected by the SMA executive committee.[138]

This was not the only time that the SMA excluded the AWST. In the late 1930s when the foremost issue in science education concerned general science, the AWST were excluded from both a joint production of a general science syllabus (and hence their critique)[139] and from a conference on general science organised by the SMA. In this, as in other cases, the AWST were forced into a position of responding rather than initiating. The issue of general science was never very important to the Association as science had long been taught in the girls' schools in a more general fashion than in the boys', but by 1937 a sub-committee was set up to prepare an examination syllabus in general science for fear that the syllabus prepared by the SMA would "be used as a basis for University examinations".[140] Owing to this syllabus the AWST were involved with the SMA on a committee to consider the JMB General Science Syllabus. Miss W.M. Casswell sat on this committee.[141] Whilst she praised aspects of the SMA syllabus, one comment does indicate that even at this level there was some kind of power struggle going on. Speaking of the syllabus she said

> "I was not allowed to put in sodium bicarbonate or any of the various things it does in cookery in Paper 1. I think it quite important, but since the men did not think it was I let it go, but I cannot think that any of us could possibly leave it out".[142]

In short, the SMA appeared to give little support or encouragement to the AWST or only did so on its own terms.[143] As a result the AWST, with the support of other female teaching associations, notably the AHM and the AAM, were forced to attempt to influence science education from a very weak institutional base, namely the girls' schools. The early links with the women's colleges of Oxford and Cambridge declined throughout the lifetime of the Association[144] and initiatives to institutionalise these links through the formation of the Joint Consultative Council failed. In 1950, Miss Sutton[145] as President - perhaps as a rationalisation, but also expressing some fact - asserted that "the aims of the women teaching science to girls is so different to that of men teaching boys that we really could not do ourselves much good by joining with them".[146] However, only nine years later Miss D.M. Scott[147] in her presidential address, looking to the future, predicted that

> "the years ahead will probably bring more science masters into our girls schools and certainly more

> part-time women staff. It is possible therefore that a very different organisation may be required and a different type of meeting. We must be ready for change and it is even probable that our aims might best be served by forming one association which would have constantly under review the development of science teaching in all its aspects".[148]

Indeed the 1950s saw the AWST begin to work more closely with the SMA. At the national level this was more on joint committees such as the Committee for the Co-ordination and Guidance of Physics Teaching and the Joint Sub-Committee for the Consideration of the Teaching of Science in Training Colleges and the association with each other on the various science panels of the examination boards. More specifically, the two associations collaborated with a questionnaire in 1953 surveying the shortage of science teachers.[149] At a local level some branches of the Association joined forces with the SMA for local meetings, such as the Cambridge Branch in 1951[150] and the Northern Ireland Branch.[151] By 1953 the AWST appeared to be seeking even closer links when a meeting of the Executive Committee agreed to "write and ask the SMA whether they would receive favourably the suggestion that in alternate years from 1955 onwards we should hold our AGM in the same building at the same time as theirs so as to be able to share their exhibition".[152]

These moves to closer links with the SMA could indicate either a convergence of interest of the two associations, a lack of clear aims on the part of the AWST leading it to append itself to the SMA, or an increasing realisation of its own lack of power to influence the science curriculum single-handed.

The evidence on this clearly points to the latter two factors. It can be shown that the AWST failed to meet the challenges of the changing educational system of the 1950s, but this failure was linked as much to its voice being ignored as to a failure to change itself. Throughout the 1950s the Association remained true to its ideals. For example, addressing the AGM in 1957, Miss J.K. Raeburn[153] noted that "this afternoon we are having a talk on technical education and it is important that we do all we can to encourage and prepare girls with the right aptitude and ability to proceed on to scientific training and a scientific career". However, she went on to warn her audience that,

> "we must not let ourselves forget that our function in schools as science teachers is to educate, not just fit, girls for the narrow groove of some particular branch of pure and applied science.... Scientific training in schools should form part of a general education. Through it the child should come to see that science forms part of our culture. We as science teachers must share with our colleagues on the Arts side the task of trying to develop balanced human beings as well as helping to give potential scientists a broad and sturdy foundation on which to base their future work and so become better scientists".[154] (my emphasis).

That the views of the AWST and SMA were not converging can be shown from one of the last public statements that the AWST made, namely its statement in support of the SMA policy document "Science and Education". In this the AWST was once again acting as a corrective to the particular bias of the SMA. The opening paragraph of the AWST statement reveals that the SMA gave little consideration to the specific conditions of the girls' schools:

> "We agree that science must play an increasingly large part in education, not only in response to the needs of the modern age, but because of its value as a cultural subject. However, while the future woman science specialist must be just as well qualified as her male counterpart, it must be realised that in a girls' school there are many of differing tastes and aptitudes whose needs must also be met".[155] (my emphasis).

Thus it is arguable that the weakness of the AWST to influence curriculum developments led to an increasing association with the SMA without any necessary convergence of views. The tension of this is neatly expressed by the AWST secretary Miss Kemlo, in her final statement at the final AGM of the AWST in 1963:

> "The formation of a new association including all teachers of science which is about to take place is surely in no way a surrender of our feminine rights or failure of feminine organisation; but is the formation of a natural partnership arising from important trends in the teaching of science to both sexes by both sexes in this scientific age. We are fully confident that our members will make a distinctive contribution to the new association and I'm sure that the interest, effort and good wishes of all our members will support the association in the same lively way

in which they have supported the AWST in all the years of its successful existence".[156]

The educational changes of the 1950s and the failure of the Association to take up the challenges these presented was another contributory factor to their weakness and eventual amalgamation with the SMA. In her presidential address for 1948, Dr. Winifred Gladwell pointed to some of the challenges of the future which the AWST had to confront. Firstly were the secondary modern schools. Dr. Gladwell suggested that the Association had little to offer teachers in these schools apart from the personal contact at branch meetings. Publications and conferences geared to the needs of such teachers were "fairly essential if this association is going to make any real contribution to the Science teaching which will in future take place in the secondary modern schools".[157] Secondly were the grammar schools. 1950 was to bring in "fundamental changes" and Dr. Gladwell saw the preceding years as an "opportunity to overhaul our courses of work, to see where we want change and to air our views".[158] The School Certificate examination was to be abolished so the Association had to decide what it wanted to substitute and why.[159] However, in spite of this awareness of what had to be done, and in spite of the strength and the clarity of the Post-Primary Reports, the Association did not clearly articulate proposals for change except, perhaps justifiably, reiterate its earlier positions. An examination sub-committee was set up in 1950, but its role was reminiscent of the earlier, defensive role of the AWST with its brief of investigating the examination requirements in science subjects in the new examinations and their possible repercussions upon the science curricula in schools, and investigating the conditions of entry to all degree courses in the science faculties in each university. The GCE examinations exactly encouraged the specialisation and the raising of standards of pass marks to which the association had so long been opposed.[160] As regards the secondary modern teachers the membership figures show that in 1962 they only accounted for less than one per cent of the total membership, suggesting that the work of the Association was not seen as relevant by these teachers.[161]

Compounding these internal problems of the AWST were the external social, economic and institutional changes of the 1950s, which began to undermine what had been the strength of the Association -

simply, the institutional network of the girls' schools and the close and friendly co-operation of the female teaching profession. The demographic structure of British society had shifted dramatically. Women were marrying earlier, families were smaller and more married women were engaged in paid work.[162] The imbalance between the sexes had changed from a situation in which women outnumbered men to the opposite of a "surplus of men", thus the teaching profession was not only suffering a shortage of the "right kind of student" to go into teaching as a result of the general skill shortage of the 1950s, but also, as the London Branch of the AWST noted in 1955, because "spinsters are a dying race".[163] The consequence was that schools saw a quick turnover of young teachers, with more part-time teachers. Thus as an association of women working principally for the science education of girls, the identity of the AWST was increasingly eroded by the rapid educational changes of the 1950s.

The final amalgamation of the AWST with the SMA to form the Association for Science Education in 1963 significantly heralded a new era of comprehensive co-education. Girls had been discovered to be "an untapped pool", "wasted", "a largely neglected source of recruitment", "the biggest untapped source of engineers". After nearly a century of social and educational policy emphasising the different needs and interests of boys and girls resulting in different curricula for them, these differences became "educational problems" in an era which suffered from a shortage of scientists and technologists. Thus by the late 1950s the AWST was an anachronism. If boys and girls had the same needs for science education and if science teachers were to strive for the same goals regardless of the sex of their pupils, there was no need for an association to promote primarily the interests of girls.

Concluding remarks.

The AWST was a comparatively small subject teaching association, unique among such associations for being women only. As a professional body, the Association overwhelmingly represented the secondary girls grammar schools, which as educational institutions were significantly different in their approaches to education from the boys' grammar schools. It is undoubtedly the case that the traditions of the women science teachers' late nineteenth century predecessors were continued by the AWST in its stress on the intellectual and cultural aspects of science education. Similarly, a distinction was made between an academic science education for the minority of girls who aimed for university and a career in science and the science education of the great majority for whom science was but one aspect of the total school curriculum. For such girls, an examination of the curriculum priorities of the AWST has shown that from the late 1920s when the Association considered the question more thoroughly, it promoted what would now be termed "girl friendly science". That is, a science education which was of relevance to girls' lives, drawing upon girls' own experiences and needs. The criteria used for such a science were the girls' own interests and the expected occupational futures of girls. Predicting modern trends in science education, the Association also consistently stressed the link between science and everyday life and the relation of science to society. I have argued that such curriculum priorities can be understood by taking account of the nature of the girls' secondary schools, the expected place of women in society and possibly a particularly "feminine" approach to science education. Arguably, this approach for girls which the AWST fostered exactly contributed to the "process of differentiation" by which girls and boys have received and continue to receive a different science education. Such an approach can be, and indeed has been interpreted in this way, notably by those who suggest that the most important science for girls is biology either because such a science is most suited to a domestic role or, more subtly, because it corresponds more closely to girls' supposed greater interest in people rather than things. Such interpretations point to the problematic nature of "girl friendly science" both as advocated by the AWST and now. In wanting to correct a male bias in science education which is seen to relate both to boys' interests and to lead to occupations which particularly in the earlier years of this century were regarded as belonging to the male sphere, there was and is a danger of making stereotypical assumptions about girls' interests and needs. That the AWST made these assumptions is possible, particularly regarding the science education of girls of lower than average ability. The reasons for making such assumptions relate both to the specific reality of most women's lives during the years of the Associations' existence and the institutional base of the membership. Few members had experience of working in the co-educational continuation schools (later the secondary modern schools) and, given the class bound nature of secondary education it is likely that the Association was not immune to making assumptions based on class as had their predecessors in the movement for the higher education of women. However, in defence, as I have argued above, even if the AWST did make these simple stereotypical assumptions about girls' interests and needs, it was not at the cost of its firm belief in a thorough grounding in experimental science for all girls based on a sound, if basic knowledge of physics and chemistry. Also, in many of the later statements of the Association, it addressed all pupils regardless of their sex and thus made suggestions for the science education of all. Importantly, the reasons why such statements were interpreted to be of relevance to girls only (in contrast to many of the statements by the SMA which were taken to be recommendations for science education per se) have much to do with the power and influence of the Association, not least its power as an association of women to make statements relevant to the education of boys.

On this point, I have argued that the AWST was relatively powerless to effect significant changes in the science curriculum. This is not to say that the existence of the Association was without significance for girls' science education. It is unlikely for example that official reports from Thomson (1918) to Norwood (1943) would have taken much notice of the situation in the girls' schools had not the AWST intended to "make themselves felt". However, it is questionable just how far the Association had any significant effect on the direction of science education. Certainly, as far as examination syllabuses were concerned, the Association could only claim small victories in the alteration of certain regulations or in its power of protest. It has been demonstrated that it could not take on the universities and the power these institutions held to shape the science curriculum through their examination requirements.

It is ironic that official concern for the lack of girls studying science and the lack of facilities for science education in the girls' schools only arose out of an economic and "man-power" crisis of the late 1950s. Such potentially powerful supporting arguments to their cause were anathema to an Association which had consistently argued for the intellectual and cultural values of science education, rather than its vocational value. The AWST joined with the SMA to form what has become a powerful and prestigious association, but it seems that in spite of new trends in science education in the 1960s which aimed to increase the number of students studying science at school, no remarkable increase in the number of girls taking up science was recorded. What was known in the 1950s was "re-discovered" in the mid-seventies. However, this re-discovery of the question of girls and science education has largely been in terms of girls' "failure" at science. Had the views of the AWST not become so invisible to these more recent attempts to understand girls and science education, then the present debate might have been more constructively situated around the failure of science education rather than the failure or inferiority of girls.

References.

1. The Association changed its name in 1922. I shall refer to the AWST throughout except when explicit reference is being made to the work of the AST.
2. As the AST it was technically open to men in that its constitution did not debar them from membership. It did have a few male members in these early years - see Layton, D., Interpreters of Science, John Murray/ASE, 1984, p.95.
3. The objectives of the AST (and later the AWST) as drawn up at their inaugural meeting in 1912 were as follows:
   a) To afford opportunities for intercourse and co-operation among those interested in the teaching of science.
   b) To provide an authoritative medium through which the opinions of science teachers may be expressed on educational questions.
   c) To discuss methods of teaching science and the correlation of school and university work.
   d) To bring science teachers into contact with those who are engaged in research work.
   e) To co-operate with other Associations for special correlation of subjects.

   Later a sixth objective was added:

   f) Generally to improve the teaching of science.

   These aims and objectives remained unchanged throughout the life of the association (to 1963) with the exception of the deletion of "for special subjects" in e). Layton, 1984, op.cit., p.97.
4. AWST AR 1949 - 1950, p.13.
5. Although, as has been discussed in chapter five, the same educational

and social advantages to teaching science to girls especially if it had domestic application.

6. Report of the Committee to inquire into the position of Natural Science in the educational system of Great Britain, H.M.S.O., 1918, p.17.
7. AST GM 23.11.12.
8. See p.216 for a discussion of this.
9. Layton, op.cit., p.105.
10. Although there are no figures available for the number of women science teachers for this period, the Directory of Women Teachers for 1913 only lists 91 science teachers (although it can be assumed that not all women teachers would have put their names forward). A BAASReport in 1917 showed that for 146 girls' schools, representing about a third of all girls' schools at this time, there were only 156 science mistresses. Thus it may be concluded that the AST was an association of approximately half the women science teachers in 1918 (membership at this date was 200).
11. Layton, op.cit., p.102.
12. Florence Storr, Secretary of the AST, 1918. Gained her B.Sc. from University College London as an external candidate in 1903. From 1897 she was Senior Science Mistress at the Central Foundation School, Spital Square.
13. AST GM 3.1.18.
14. Prior to the 1944 Education Act these schools were simply referred to as secondary schools. With reorganisation these became the grammar schools to distinguish them from the secondary modern and the technical schools.
15. Miss K.N.H. Chapman, County High School for Girls, Woodford Green, Essex (1953-1954).
    Miss P.M. Taylor, ex Girls High School, Southend on Sea. (1951-1952).
16. Miss J.K. Raeburn (1955-1956).
17. Miss E.L. Buckley, The Grey Coat Hospital, Westminster (1961-1962).
18. Dyhouse, C., "Towards a 'feminine' curriculum for English schoolgirls", Women's Studies International Quarterly, vol.1, 1978, pp.291-311 (p.299).
19. See, Lowndes, G.A.N., The Silent Social Revolution, Oxford University Press, 1970; Simon, B., The Politics of Educational Reform, 1920-1940, Lawrence and Wishart, 1974.
20. For details of this work see, Arnot, M., "Culture and Policital Economy - Dual Perspectives in the Sociology of Women's Education", Educational Analysis, vol.3, no.1, 1981, pp.97-116.

21. Lowndes, op.cit., chapter six.
22. S.S.E.C., Curriculum and Examinations in Secondary Schools, HMSO, 1943.
23. Board of Education, Report of the Consultative Committee on Secondary Education with special reference to Grammar Schools and Technical High Schools, H.M.S.O., 1938.
24. David, M., The State, the family and education, R.K.P., 1980, p.69.
25. T.E.S. 5 August 1944, p.379.
26. C.A.C.E. (England), 15-18, A Report, Vol.1, H.M.S.O., 1959, p.22.
27. Banks, O., Parity and Prestige in English Secondary Education, R.K.P., 1955, p.193.
28. Dent, H.C., Secondary Modern Schools - An Interim Report, R.K.P., 1958, p.143.
29. David, op.cit., p.73.
30. Salter, B. and Tapper, T., Education, Politics and the State - The theory and practice of educational change, Grant McIntyre, 1981, p.139.
31. ibid.
32. Arnot, op.cit.; David, op.cit.; Wolpe, A.M., "Education and the Sexual Division of Labour", in Kuhn, A. and Wolpe, A.M. (eds.), Feminism and Materialism, Virago, 1978.
33. Board of Education, Report of the Consultative Committee on Differentiation of the Curriculum for Boys and Girls Respectively in Secondary Schools, H.M.S.O., 1923.
34. Central Council for Education, Half our future, a report, H.M.S.O., 1963.
35. Wolpe, A.M., "The Official Ideology of Education for Girls", in Flude, M. and Ahier, J. (eds.), Educability, Schools and Ideology, Croom Helm, 1974, pp.138-159.
36. Wolpe, A.M., Some Processes in Sexist Education, Women's Resource and Research Centre, 1977, p.5.
37. Arnot, op.cit., p.102.
38. Ministry of Education, Technical Education, H.M.S.O., 1955-1956, p.21.
39. Board of Education, 1923, op.cit., p.156.
40. See, for example, T.E.S. Jan.20, 1984, p.11.
41. Partington, G., Women Teachers in the 20th Century in England and Wales, N.F.E.R., 1976, pp.28-36; David, op.cit., p.155.
42. Brock, W.H., "From Liebig to Nuffield - A bibliography of the history of science education, 1839-1974", Studies in Science Education, vol.2, 1975, pp.67-97; Jenkins, E.W., From Armstrong to Nuffield, John Murray, 1979; Uzzell, P., "The Changing Aims of Science Education", SSR, vol.60, no.210, 1978, pp.7-20.

43. "The essential mission of school science is thus to prepare pupils for civilised citizenship by revealing to them something of the beauty and power of the world in which they live, as well as introducing them to the methods by which the boundaries of natural knowledge have been extended...." Gregory, Sir R., "Education and School Science", Presidential Address to Section L (Education) at the BAAS meeting, 1922, BAR, 1922, p.206.

44. This is dealt with fully in chapter four.

45. AST GM 3.1.18.

46. Report of the Committee to inquire into the position of Natural Science, op.cit., p.80.

47. ibid.; Similar information was also furnished to the British Association committee considering science in secondary schools. Their report published the following table:

Laboratory Accommodation in Girls' Schools.
89 Typical Girls' Schools.

No. of Girls in School	No. of Schools	1 Lab.	2 Labs.	3 Labs.	4 Labs.
100-200	38	35	1	1	1
200-300	28	20	7	1	0
300-400	13	10	1	2	0
400-500	10	-	4	5	1

(BAR 1917, p.206).

48. Staffing in Girls' Schools.
146 Typical Girls' Schools.

No. of Girls in School	No. of Schools	No. of Science Staff 1	1+	2	2+	3	3+	4	5
100-200	59	46	7	5	-	1	-	-	-
200-300	42	19	9	8	2	4	-	-	-
300-400	30	3	2	16	6	2	-	2	2

1+ means that there is one full time and one part time mistress and so on. (BAR 1917, op.cit., p.206).

49. Report of the committee to inquire into the position of natural science, op.cit., p.80. Women science graduates were a minority of women graduates, accounting for only 18% of women who took a Tripos between 1881-1916 (MacLeod, R. and Moseley, R. "Fathers and Daughters - Reflections on Women, Science and Victorian Cambridge", History of Education, vol.8, no.4, 1979, pp.321-333). Before 1914 a very great

majority of these graduates went into teaching. During and after the 1914-1918 war the attitude of State and Industry changed towards science and technology and they began to compete with Education for "the services of those, who, in former times would have looked forward to science teaching as a profession". (Jenkins, op.cit., p.223).

50. AWST AR 1934, p.23.
51. ibid., pp.22-23.
52. AWST EM 17.4.42.
53. ibid.
54. AWST EM 4.1.35. and 1.6.35.
55. Industrial Fund for the Advancement of Science Education in Schools, Final Report of the Executive Committee, Dec. 1963, p.19.
56. "Women Scientists in Industry", T.E.S. Sep.28, 1956, p.1165.
57. "Sixpence a year for science", New Scientist, Aug. 15, 1963, p.326.
58. AHM Report 1929, pp.108-109.
59. "In considering the curriculum of the VIth Form there are three groups of girls for whom arrangements must be made : 1. Those who are working for University Scholarship, Higher School Certificate, Civil Service or similar examinations. 2. Those who are going to take up commercial work. 3. Those who intend, after staying at school for one or two years, to follow some occupation which does not mecessitate the taking of further examinations while at school". AAM, Memorandum on sixth form life and work in girls' secondary schools, with special reference to the non-examination pupil, University of London Press, 1939, p.8.
60. AWST AR 1926, p.41.
61. Miss M.B. Thomas 1873-1954. President of the AWST 1921, 1922. Director of Studies in Chemistry, Physics and Mineralogy and lecturer in chemistry, Girton College, Cambridge.
62. Nature, vol.CXI, Jan.20, 1923, p.100.
63. AWST AR 1939, p.44.
64. These were:
    - 1915 : Extraordinary General Meeting to discuss the syllabus in Chemistry, Physics, Botany, Zoology and Geology, suitable for girls 16-18.
    - 1931 : Science for Girls in Post-Primary Schools. A scheme drawn up by the North-West Branch of the AWST.
    - 1937 : Comments on the SMA General Science Syllabus.
    - 1939 : General Science Examination Syllabus.
    - 1944 : Interim Report on Reconstructional Problems in Post-Primary Science Education.

1946 : ditto, part 2.

1947 : ditto, part 3.

1957 : "Science for Girls in Secondary Modern Schools", in, SMA, Secondary Modern Science.

1959 : The Place of Science in the Girls' Grammar School - a statement published by the Executive Committee of the AWST.

65. AWST, Interim Report on Reconstructional Problems in Post-Primary Science Education, Part I, John Murray, 1944, pp.2-3.
66. AWST EM 7.1.17.
67. ibid.
68. Miss C.M. Taylor, President AWST 1925, 1926. Headmistress of Northampton School from 1921. Educated at Victoria College, Wellington, New Zealand, and Newnham College, Cambridge. MA Class II Hons., Chemistry. Taught at Clapham High School 1912-1913; St. Paul's Girls' School 1913-1921.
69. AWST AR 1926, p.6.
70. Miss Isabella M. Drummond. President AWST 1916, 1917, 1930, 1931. Science mistress at the North London Collegiate School from 1908, Head Mistress at the same school 1918-1940. Educated at Oxford High School. 1st Class Honours in Natural Science (Zoo.) from Oxford in 1900, Oxford Teaching Diploma with Distinction in 1902. Taught at the Girls' High School, Loughborough, 1902-03, Edgbaston High School 1903-1907.
71. Drummond, I.M., "Science in Secondary Schools for Girls", The New Era, Jan. 1932, pp.10-12 (p.10.)
72. AWST AR 1939, p.42.
73. ibid.
74. ibid., p.45.
75. AWST AR 1934, p.22.
76. This begs the question why only a minority of girls? This is a question which interestingly the Association never really addressed. It accepted that only a minority of girls would become "specialists", probably a realistic assessment given the structure of the labour market then and now. Importantly the Association always understressed the vocational aspects of science education and stressed its value for all girls.
77. At a general meeting in 1921 "a discussion followed on the motion of Miss Lees that group III is an essential part of the General School Examination. In her remarks Miss Lees stated that it was unnecessary to labour the point as to the necessity of group III, but she merely wished for an expression of opinion from the Association which would safeguard

the position of Group III in the Exam. That this was necessary the recent action of the AHM and AAM had shown. The former had passed a resolution that group IV be taken as an alternative to II or III and the latter were considering it. Mrs. Gordon Wilson seconded the motion which was carried by a large majority". (AST GM 4.1.21.). Again in 1927 Miss Lees wished to propose a resolution against the move that "Group III should no longer be compulsory". (AWST GM 18.11.27.)

78. AWST EM 4.2.28.
79. At a meeting of the Executive Committee in 1944, Dr. Gladwell, who represented the Association on the University of Cambridge Joint Advisory Committee for Biology, Botany and Zoology, spoke of "the adamant attitude of the University of London with regard to the 1st MB syllabus. Prime concern of these committees was with boys, probably because statistically many more boys than girls take the Cambridge Higher School Certificate Science papers". (AWST EM 22.1.44.)
80. Drummond, op.cit., p.11; AWST, Interim Report on Reconstructional Problems in Post Primary Science Education, Part 2, John Murray, 1946, pp.1-6.
81. For example, in 1930 the Association protested to London University about various points in the chemistry and biology papers in the London General Science Examination, noting that "technical processes are not desirable at the age of the candidate for this exam" (AWST EM 5.7.30). In 1932 it wrote to the NUJMB saying that it was time to omit questions on physics and chemistry in the botany examination of the NUJMB School Certificate (AWST EM 28.5.32). In 1933 it wrote to the NUJMB on the need for a chemistry/physics paper, (AWST EM 20.5.33). During 1942 the Executive Committee unanimously agreed that "the AWST should take part in any replanning of the first part of the pre-clinical" and the Secretary was advised to apply to the Royal College of Physicians "stating our objective" (AWST EM 17.4.42.)
82. AST GM 13.11.15.
83. AWST, "General Science Report - Comments by the A.W.S.T.", SSR, Oct. 1937, pp.134-5.
84. AWST, "Science for Girls", in SMA, Secondary Modern Science Teaching, Part 2, John Murray, 1957, pp.141-149, (p.145).
85. AWST, 1937, op.cit., pp.134-5.
86. AWST, 1957, op.cit., p.145.
87. AWST AR 1937-1938.

88. AWST/AAM, A General Science Examination Syllabus, John Murray, 1939.
89. This is interesting in the light of more recent discussion of girls' education in science. The APU explain the discrepancy between boys and girls on questions of electricity by the differential experiences of boys and girls in their everyday, out of school activities. When questions concerning electricity were framed in ways familiar to girls' experience, their performance improved. See, Johnson et al., "The Science Performance of Boys and Girls", Contributions to the 2nd GASAT Conference, Institute of Physics, Oslo University, Norway, 1983, pp.93-107.
90. AWST EM 27.11.43.
91. AWST EM 16.4.31.
92. AWST 1944, op.cit., p.7.
93. AWST 1937, op.cit., pp.134-135.
94. AWST/AAM, 1939, op.cit.
95. ibid.
96. Regular reports of these bodies were made in the Association's Annual Reports.
97. As a sub-committee of the BAAS reported in 1933, "it is fair to conclude that in boys' and mixed schools, chemistry and physics dominate the science work and in girls' schools there is a wider field". BAR 1933, p.319.
98. Unlike assumptions made by other educational bodies. See Wolpe 1974, op.cit.
99. AWST, 1957, op.cit.
100. "Needs" relating to future occupation, paid or unpaid. In the Crowther Report, for example, it was noted that since the 1930s the greatest increase in fields of work for women was clerks and typists. In professional fields women did nursing, medical services, teaching and social work, but the proportion of women in these occupations in 1951 was lower than men than in 1931. (C.A.C.E. op.cit., p.30). Of girl school leavers in the late 1950s, among grammar and technical school girls 15% went on to full time education, 15% went on to some form of professional occupation, 62% went on to a non-manual occupation and 4% took up manual work. Among modern school girls, 53% took up some form of non-manual occupation and 39% manual work. (C.A.C.E., op.cit., Vol.ii, p.35-36).
101. AWST, 1957, op.cit., p.144.
102. No biographical information is available either for Miss Legh or Miss Whitworth.
103. Speaking of teachers in the Secondary Modern schools in a symposium on

"The Training of the Science Teacher", Miss Whitworth stressed not so much the need for academically trained teachers, but rather those "with as broad a basis of scientific knowledge as possible, people with lively enquiring minds who are capable of capturing the children's interest so that their pupils are helped to understand their environment and come to regard science, not as some pedantic study, but as something of tremendous relevance to their everyday lives". She went on, "if I could have only one science teacher on the school staff my personal choice would be for a biologist, but I should want that biologist to have a sound knowledge of physics and chemistry". (AWST AR 1958-9, pp. 11-12).

104. Nature, 1923, op.cit.
105. Drummond, op.cit., p.12.
106. Board of Education, 1923, op.cit., p.103.
107. AWST AR 1934.
108. AWST, 1944, op.cit.
109. AWST, 1946, op.cit., p.3.
110. As with some forms of "progressive" education.
111. These fundamental differences also gave rise to a series of other differences. For example, the SMA was larger, the members overwhelmingly came from the boys' public and grammar schools and thus had access to considerable power and prestige; also the associations organised themselves differently - the AWST a group of mainly single women seeking contacts, friendship and co-operation as well as professional advancement; the SMA a more formal professional association - see Layton, 1984, op.cit., for a full comparison of the two associations.
112. AWST, Interim Report, 1944, 1946, 1947, op.cit.
113. IAAM/SMA, The Teaching of Science in Secondary Schools, John Murray, 1947. Although this was written jointly by the IAAM and the SMA, most of the IAAM members involved in writing the book were also SMA members.
114. AWST, 1944, op.cit., p.1.
115. ibid., p.2.
116. IAAM/SMA, 1947, op.cit., pp.10-11.
117. ibid., p.11. While it is true that the AWST used the phrase, " the struggle of mankind to master nature, to become free" (AWST, 1944, op.cit., p.3), this was in the context of "topics for discussion", and does not necessarily imply a commitment to that view.

118. This deserves a much fuller treatment perhaps following Carolyn Merchant's work on symbol and metaphor in science ("Isis's consciousness raised", ISIS, vol.73, 1982, pp.398-409). The problem here of course is material. This is one reason why I felt unable to pursue such a line of inquiry, also, as I attempt to argue in the text, there were several other social and material factors which influenced the views of the AWST.
119. "Science education in the future : Many members considered this an important topic to consider at once, so that when the views of the Association were sought in future there would be material at hand for the Executive to refer to." (AWST EM 23.1.43.).
120. "Science in Post-Primary Education", Nature, vol. 154, 1944, p.793.
121. "Science in Post-Primary Education", Nature, vol. 157, 1946, p.797.
122. Lauwerys, J.A., "Reforming Examination Syllabuses", Journal of Education, vol.LXXVI, 1944, p.608.
123. Weatherall, R., "Post-Primary Science", Journal of Education, vol.LXXVII, 1946, pp.286-287.
124. An indication of the general ignorance of this report is the total lack of discussion of the AWST or their work in Uzzell 1978, op.cit., or Brock, 1975, op.cit. Whilst Jenkins, 1979, op.cit., does discuss the AWST briefly, he gives no mention of this report.
125. For example, in 1938 the AWST had representatives on the BAAS; the Women's Employment Federation; the English Speaking Union; the League of Nation's Union; the National Council for the Teaching of International Relations; Educational and General Services; the Advisory Council for Educational Films; the International Peace Campaign Conference - Science Section; the British Social Hygiene Council; the Electrical Association for Women.
126. AST EM Dec. 1918.
127. It was reported to the Executive Committee in 1926 that the AAM had appointed a special science panel. It was decided to send the following letter: "....the AWST....aware of the science panel of AAM members. The Association welcomes the formation of this and will be grateful if it may be kept in touch with the activities of the panel. From the size of its membership and from the fact that its members are drawn from both schools and universities, the AWST is more completely representative of women science teachers than any other association. The committee wish to say that the Association will be glad to give its experience and its help in achieving those objects which the AWST and the panel have in common". (AWST EM 8.10.26.)

128. cf. AWST 1937, op.cit.,; AAM/AWST, 1939, op.cit.
129. Nature, vol.102, 1919, p.436.
130. ibid.
131. Originally it was intended that the Council should be formed by one representative of each of the eleven universities then in existence - Oxford, Cambridge, London, Durham, Victoria, Birmingham, Liverpool, Leeds, Sheffield, Bristol, Wales; three representatives from each of the four school associations - the AHM, HMA, APSSM and AST, and representatives from the women's colleges at Oxford and Cambridge (AST EM 7.1.19.). Whilst one of the earliest meetings was attended by seven university representatives and representatives from the four school associations (Nature, 1920, op.cit.), by 1925 a meeting of only nine members was recorded - Miss Kirkaldy (Oxford), Miss Easthough (Chair) and Miss Byrne (Sec.), Miss Carruthers and Miss Ridley (AWST), Mrs. Gorden-Wilson (Co-opted AHM., AWST), Dr. Stevens and Mr. Wagstaff (HMA), Professor Weiss (University of Manchester) - two university representatives and seven school representatives (SSR, vol.vii, Sept. 1925-June 1926, p.49).
132. AWST EM 22.11.29.
133. AWST EM 5.7.30.; 5.1.31.
134. Letter from E.E.C. Baly to Miss M.E. Birt, AWST EM 18.5.33.
135. AST EM 9.11.21.
136. SSR, 1925-1925, op.cit., p.48.
137. AST EM 24.3.22.
138. Jenkins, op.cit., p.100; Layton, op.cit., p.33.
139. AWST EM 28.3.36.
140. AWST AR 1937-1938.
141. Miss W.M. Casswell, 1888-1980. Educated at Lincoln High School, B.Sc. from University of London in botany and chemistry. North West Branch representative on Executive Committee in 1920. Assistant Mistress, Withington Girls' School, Manchester, then Headmistress, Edgbaston High School, Birmingham. President, AWST, 1945. Hon. member 1947. Although she sat on the committee which considered the JMB General Science syllabus, she was not representing the AWST.
142. AWST AR 1938-39, p.66.
143. An example here is in the Chapter "Science for Girls" written at the request of the SMA by two members of the AWST. However, throughout the chapter the SMA committee footnoted its points of disagreement - a right of reply that it did not give the AWST.
144. This point was made by Miss Sutton in 1950: "The other point is about

women University members, they have largely dropped out. Perhaps it was our fault, perhaps we did not provide for their interests. We have very few university lecturers among our members now. I suppose in the Branches you probably have them come and talk to you sometimes but we do not have them on the Executive. It seems to me that we have let this contact go and I am very concerned about it for this reason. You all know of the dreadful dearth of science teachers, especially in physics. I was told by a headmistress...that her association is very concerned about that also and they feel we are losing touch with University work. Methods of research are changing enormously and our teaching is getting more and more divorced from pure science; we are having to teach so many children who are quite incapable of anything of the sort that we are perhaps not keeping the best children sufficiently in touch. I know that we are supplying good people for the Universities , but somehow we are not getting the contacts we might". (AWST AR 1949-50, p.15).

145. Miss Mary Sutton; Science mistress, St. Martin's High School, Tulse Hill, London Branch member; AWST Executive Committee member 1930-34; Co-opted member 1936-39, President 1949-50.
146. AWST AR 1949-50, p.14.
147. Miss D.M. Scott; educated at Girton College Cambridge(date ?) Science Mistress, Manchester High School for Girls; AWST President, 1957-58.
148. AWST AR 1957-58, p.11.
149. AWST AR 1952-53, p.5.
150. AWST AR 1950-51, p.22.
151. AWST AR 1951-52, p.29.
152. AWST EM 10.7.53.
153. Miss J.K. Raeburn, science mistress, North London Collegiate School; London Branch member; AWST President, 1955-56.
154. AWST AR 1955-56, p.11.
155. AWST, The Place of Science in the Girls' Grammar School, John Murray, 1959.
156. AWST AR 1962.
157. AWST AR 1947, p.15.
158. ibid., p.19.
159. ibid., p.18.
160. The Association registered their objections to this in the form of resolutions at an AGM in 1953: "That this Association feels that in some of the A level Science Exams the standard of pass is higher than should be expected and that any raising of the standard would be

deplored", "That the Association is of the opinion that sixth form work in grammar schools would be encouraged and strengthened by the institution of an examination recognised as intermediate in standard between O and A levels and that this standard should be endorsed on the certificate..." (AWST AR 1953).

161. Although it should be noted that with the shortage of science teachers in the 1950s it is likely that there were far less science teachers in the secondary modern schools than in the grammar schools.

162. C.A.C.E., vol.2, op.cit., pp.28-30.

163. AWST LB EM 10.3.55.

7. Conclusion : Girls and science education - continuity in a changing context.

In spite of nearly three decades of concern regarding the sex-differentiation to be found within science education, strong sex differences remain. A recent report from the National Foundation for Educational Research has noted that

> "in nine major academic subjects the pattern of take-up by pupils in 1980-81 differed little from that found by the HMI in 1973. More boys than girls took physical sciences and technical subjects: more girls than boys took biology, vocational subjects (like office practice) and languages".[1]

The sex-differentiation in science education has most often been conceptualised in terms of a problem for, and about girls. Positive action has been concerned to increase girls' participation in science education, particularly in the physical sciences. Such action has generally been directed at changing girls' attitudes towards the sciences and science-related careers. The socio-historical perspective of the work presented above, which has placed this contemporary concern in a much broader context, indicates the need for an alternative view on the "girls and science" problem. Three points are relevant here. Firstly, although the sex-differentiation within science education has only been regarded as a problem since the late 1950s, and especially so since the mid-1970s, sex differences have existed at least since the formal establishment of science education in schools when different conceptions of science education for boys and girls were developed. The second point to note is that sex-differentiation in science education cannot be explained simply in terms of the different attitudes held by boys and girls towards science subjects. Thirdly, the over emphasis on attitudinal explanations has led to a restricted conception of the problem of a sexually differentiated science education. By conceiving the problem as one for, and about, girls, girls, teachers, parents and employers have been the focus for change rather than science education itself.

In an attempt to understand the significance of gender in the development of school science education and the science curriculum, this thesis has offered evidence in support of the view that the problem of girls and science should be re-formulated as a problem for, and about, science education (and education in general) and the social context in which it is situated. Instead of asking, "why do girls fail at science?", the alternative questions of how and why science education for girls developed, how science education was defined for girls and the reasons for this have been addressed. An attempt has been made to demonstrate that the contemporary sex differences in science education have been the result, at least in part, of a particular socio-historical process. This is not to deny that social-psychological factors, or even some biological factors, are unimportant in the sexually differentiated patterns of science choice and achievement. However, the exclusive concentration on these factors as explanations for the current situation has led to a narrow definition of the problem which, in turn, has led to the wrong questions being asked and, perhaps, the wrong conclusions being drawn.

This chapter reviews the various aspects of the socio-historical process involved in the development of a sexually differentiated science education and considers the value of a socio-historical perspective on current attempts to increase girls' participation in science education. A final section will examine themes for future research within this socio-historical approach which have been suggested by the present inquiry.

Continuity in a changing context.

To explain the development and definition of science education for girls it is necessary to consider several contextual factors : women in social context; the educational context and the institutional context of girls' education.

Women in social context:

It has been argued throughout the preceding chapters that ideas about women's function in society have had a significant effect upon the provision of science education for girls. Throughout the period examined by this study the scope of women's social role has broadened considerably. No longer restricted to the early nineteenth century hearth and home, women have made considerable inroads into all aspects of public life. The stereotypic family unit headed by the father and breadwinner has been weakened by a rising divorce rate and the emergence of alternative family forms. Motherhood and direct family commitments, if at all, only represent a fraction of a woman's adult life. However, in spite of the manifest changes in women's social role, what has remained remarkably constant is the "ideology of femininity", discussed in chapter two, and the related assumption, reflected in educational and social policy, that woman's primary role is the domestic role.[2] In spite of changes in the economic structure of society which have resulted in the demand for women to enter the scientific and technological labour force, no radical re-structuring of the domestic context has taken place. "Women's work" is still defined as work which is compatible with child-care responsibilities and family commitments. This "ideology of femininity" and the assumptions that go with it has been of significance in the other contextual factors to be discussed below.

The educational context:

The educational context has changed dramatically throughout the nineteenth and twentieth centuries. Whilst the early nineteenth century saw little or no formal educational provision, particularly for the children of industrial and agricultural labourers, by the late nineteenth century a national system of education had developed, organised on class and sex lines. The patterns set down at this time lasted well into the twentieth century, to be superseded in the post-war period by a co-educational and comprehensive system.

This changing context of educational provision has had important consequences for the development of girls' science education. Until the mid-twentieth century the sex and class of pupils were major determinants of the nature of science education they received. In chapter two the situation before education was institutionalised was examined and it was shown how science education, through the medium of popular scientific texts, had religious and moral functions. For girls, ideas transmitted in these texts were compatible with contemporary views about the nature and function of women's education.

Later in the nineteenth century a system of state run elementary education for working-class children developed. Two possibilities for science education emerged in the contrasting schemes of Dawes and Henslow.

It was argued in chapter three that it was a reconstituted form of Dawes's conception of the "science of common things" that acted as a model for science work in the elementary schools after 1870. This form of science education attempted to relate the subject matter to the children's everyday experience. For girls this meant the development of a science education closely related to domestic applications. Thus domestic economy, hygiene and physiology were the three sciences which dominated the scientific education of girls in the elementary schools. Even in the more innovative schemes in experimental science evident at the end of the nineteenth century, domestic application was both the rationale for girls' science education and provided the examples to illustrate their lessons.

Within the elementary education system, sex differences in science education appeared to transcend regional differences. Whereas science education tended to be geared to the needs of the locality - for example, agricultural education in rural areas contrasted with, perhaps, mechanics in urban/industrial areas - domestic economy for girls was universally advocated. On this point, however, it would be interesting to discover how far, if at all, the urban/rural distinction entered into the domestic economy education of girls.

For girls of the middle and upper classes the early nineteenth century tradition of education either at home or in small proprietory schools continued throughout the century and into the twentieth century. The earlier tradition of science education for girls evident at the beginning of the nineteenth century also continued in this type of education, with botany, astronomy and "the use of the globes" predominating. For a significant minority of girls, however, demands for the secondary and higher education of women resulted in the establishment of the girls' high schools which were founded on the conviction that girls were the intellectual equals of boys. Chapter four discussed the alternative definitions of science education which developed in these schools. "Academic" girls followed courses in the physical and biological sciences, while the less motivated or the less academically minded tended to be offered a science education related to their "practical" interests. This was an education related to an assumed domestic future. This pattern of science education for girls established by the girls' high schools was the model followed in the girls' secondary schools which developed after the 1902 Education Act and it remained visible well into the latter half of the twentieth century.

Throughout the nineteenth and twentieth centuries the sex and class differences in science education were quite overt, following the sex and class divisions of educational provision in general. The historical examples discussed in the preceding chapters show that, with the exception of a minority of "academic" girls following science courses determined in large part by external examination boards and the universities, science curricula for girls and boys and for girls in different types of school, were significantly different.

Since the 1944 Education Act educational provision has become increasingly co-educational and comprehensive. Class and sex have ceased to act as overt selective criteria for schools (with the exception of the independent schools and the minority of single-sex state schools), yet differences in the education of boys and girls, including in science education, have remained. This situation has been sustained by a covert process of sex segregation. A "hidden curriculum" operates within the classroom which, in spite of formal claims to the contrary, "differentiates on the grounds of sex".[3] In spite of the assertion that boys and girls are treated the same in the educational system in general, and in the classroom in particular, there is strong evidence to suggest that sex is still an important criterion for educational policy makers and for teachers. Wolpe has shown in her study of the Norwood, Crowther and Newsom reports that,

> "Where they have considered educational problems for girls as distinct from boys they have revealed that they have presupposed what will and should be the lives of girls as adults".[4]

A more recent survey, conducted six years after the 1975 Sex Discrimination Act made sex discrimination in education unlawful, has shown that whilst most schools do not actually break the law, only a minority (some ten per cent) have strong equal opportunities policies. As the authors of the report state, "neutrality" with respect to equal opportunities policy "maintains the status quo, with its evident differentiation and sex-stereotyping".[5]

Thus, in spite of changes in educational provision towards co-education and comprehensive schools - changes which were motivated by egalitarian principles - no significant differences have been evident in educational outcomes. Classroom observation of mixed classes has shown that although teachers think that they are treating all pupils equally, the way they manage the science lessons - how they organise seating, registers, practical work, question and answer sessions - almost invariably favour boys.[6] In experiments with single-sex and mixed-sex classes girls in single-sex classes have performed better in science than those in mixed-sex classes. The questions confronting science educators now, both in England and elsewhere is how far mixed-sex education actually works against egalitarianism and whether segregation is once again necessary to give girls equal chances in science.[7] The historical evidence does not altogether support the view that single-sex education necessarily improves girls' opportunities in science - not least because of the institutional context, to be considered below. What the evidence does show is that as important as the type of school is the context in which it is situated. What is at issue here is the relationship between education and society. To date neither co-education, nor the single-sex education which preceded it, have promoted equality of opportunity or outcome because they have been situated in a wider social context in which "the very structures, practices and beliefs are marked by socially constructed gender divisions".[8] In the face of this Deem notes that, "the sexes do not stand equal on admission to secondary school and, offering both girls and boys the same opportunities and facilities cannot lead to equality of opportunity, still less equality of outcome".[9]

The institutional context:

The institutional context of girls' education has had an important effect upon the development of science education for girls, particularly in the girls' high schools and later the girls' grammar schools. Overall, one of the most significant factors discussed in chapter four, was the aim of these schools to give a balanced, liberal education. The demands of science education had to be considered along with education in mathematics, languages and the humanities, as well as the traditional "accomplishments" which still found their place in girls' education. A very full curriculum had to be fitted into a school day which, until the early years of the twentieth century, was only the length of an extended morning. Undoubtedly, prior to the statutory minima laid down by the Board of Education (minima which were fiercely opposed by the Headmistresses Association), the amount of time given to science education would have been a matter for internal school policy. The lack of science and mathematics graduates among headmistresses was certainly a factor identified by the AWST which had negative consequences for girls' science education.[20] A further factor here was the partial, if not complete, dependence by the early headmistresses on parental wishes. The shortage of public funds for girls' education meant that the survival and success of a school rested on an adequate number of pupils enrolling. Parents were at liberty to withdraw their daughters if they believed that the education they were receiving fulfilled no useful purpose. Parents did not always see the need for their daughters to learn science[11] and such parental resistances had to be carefully overcome by the headmistresses.[12]

The poverty of girls' education had very particular consequences for science education in terms of the shortage of laboratories, equipment, teachers and laboratory assistants. Such shortages remained a consistent feature of girls' science education in the girls' schools throughout the twentieth century. This not only presented the difficulties of providing all girls with a full science education but had consequences for the curriculum as well. It was suggested, both in chapter four and six that factors such as lack of laboratory space or equipment may have influenced curriculum priorities for women science teachers in the high schools.

Today, in the co-educational setting, it cannot be claimed that girls' education suffers from this poverty in relation to boys' education. However, there is evidence to show that girls are losing out because there is not enough money to provide the extra provision which is recognised as necessary "if girls are to be given a grounding in science equal to that of boys without reducing the opportunities of the latter".[13] Evidence has shown that boys are given preference over girls if there is a shortage of equipment,[14] or, even if boys are not given preferential treatment, in a situation in which there is not enough equipment, girls generally go without, or wait until the boys have finished.[15] More recently similar imbalances appear to be developing within technology education. One report has noted that,

> "even in the information technologies computers tend to be regarded as 'boys toys' and there are widespread fears that female students are being elbowed out of practical computing experience...."[16]

More resources are now being requested for technology education to ensure that it finds its place on the curriculum as part of a balanced education and not just as a predominantly male, vocational training.[17]

In continuity with the earlier traditions of girls' education, parental expectation and career guidance still tend not to associate girls with science and future scientific jobs.[18] Regional factors may however be important here. One survey noted that in towns dominated by engineering and manufacturing industries there is often a higher level of expectation that girls will take science.[19] Such regional variations would be worthy of further investigation as factors which have influenced the provision of girls' science education.

As in the earlier period of the late nineteenth and early twentieth centuries there are still shortages of women science teachers. There are fewer women science teachers than men in all types of school and women science teachers are generally to be found at the lower end of the teaching hierarchy.[20] Whilst there is no conclusive evidence as to how far a woman science teacher provides a positive role model for girls,[21] at the very least the lack of women teaching science in school contributes to the prevailing "masculine image of science". For the teachers themselves, it would be interesting to speculate how far the eclipse of single-sex educational establishments by co-educational schools has led both to a restriction of their career opportunities and a loss of professional contact with other women science teachers.[22]

It may well be the case that the institutional constraints on girls' education in the nineteenth and early twentieth centuries, particularly with regard to the resources available for science education, have been alleviated by the greater facilities available to mixed schools. However, it may also be the case that these earlier problems have been equally matched by the new problems arising for girls in the mixed setting.

Having dealt with the constraints of the institutional context of girls' education and particularly those of the girls' high schools, it is necessary also to consider some of the positive features of this context. In terms of pupils' ability, if not class composition, the girls' high schools were truly comprehensive. They were not vocationally orientated schools as were many of the middle-class boys schools which prepared boys for a variety of clerical and professional occupations. The sixth form of the high schools was not simply composed of girls aiming for university or the professions but also girls following non-examination courses and learning practical skills which would help them secure a job, or run a home. It was recognised by the headmistresses and the science mistresses that only a minority of girls would want, or need, to follow academic science courses. However, science was regarded by them as an important part of a balanced education and whatever the nature of the science course pursued the same educational goals underpinned the science education of all. It was repeatedly stressed that science education found a place in the girls' high schools because of its importance as an intellectual discipline and as a method which was transferable to other situations. Practical interests - whether of teaching a girl the principles of bread-making or preparing a girl for university entrance - were subordinate to these educational goals. By contrast, contemporary science education appears to be dominated by the academic tradition and the needs of the minority determine the provision for all.[23] The broadly educational goals appear to have been lost to the requirements of external examinations and the vocational emphasis which tends to be attached to science education from the time that option choices are made at the age of thirteen.[24]

Versions of science education for girls : socio-historical perspectives and contemporary initiatives on girls' science education.

Girls' science education has been shaped by the specific socio-historical factors discussed above. Their influence has both led to the exclusion of girls from education in the higher status sciences and to the development of a subordinate science curriculum for girls. This process was evident in the early nineteenth century when women were denied access to the newly formed scientific associations. In the elementary education system a science education was defined for girls in terms of domestic applications to ensure the future efficiency of domestic servants and working-class wives and mothers. Within girls' secondary education the women science teachers both had to respond to the demands made on the science curriculum by the existence of external examinations in order to prove that girls were the intellectual equals of boys and to the social demand that girls learn the skills deemed appropriate for the feminine role. From the earliest days of the girls' high schools it was recognised that courses developed specifically for girls, however good these were, would never be regarded as highly as courses which were taken by boys. The women science teachers were thus caught in a double bind. They either had to conform to courses which had initially evolved for boys in relation to male vocational outcomes such as the army, or the medical profession, or they had to choose the alternative of science courses relevant to the ideal feminine role : hygiene, physiology, "domestic science" and biology. The experience of the AWST demonstrated what little power a women's organisation wielded in the face of the combined influence of the universities, examination boards and the boys' public schools and their ability to define the science curriculum for <u>all</u> pupils.

In the present context there is a general commitment to equal opportunities in school and a genuine desire to increase the participation of girls in science education. Positive action is viewed in three ways. The first is to persuade girls to enter into existing science schemes by employing a variety of strategies, all of which seek to demonstrate that science is an acceptable and worthwhile pursuit for girls. Such strategies include visits to schools by practising women scientists and engineers, girls-only science clubs, girls-only science classes and the removal of barriers created by option schemes which place subjects like physics against a traditionally feminine option such as French or history. The second is to advocate changes in the science curriculum to make it more "girl-friendly". The main point suggested here is to replace some of the traditional examples from physics or chemistry which reflect typical boys' interests with examples in which girls show a greater interest.[25] Such a strategy does not have to be at the expense of boys as considerable areas of overlap of interest have been demonstrated.[26] The third possibility develops out of this and would seek to modify existing science schemes for all.[27]

Amongst what might be described as the "girls and science movement" composed principally of women science educators and educational researchers, it is the latter two options, with their focus on changing the science curriculum, which generally find most favour. However, in most initiatives which have sought to increase the participation of girls in science, it is the first option which has most often been selected. The reasons for this strongly echo the dilemmas faced by women science teachers earlier in the century. Firstly, as argued in chapter one, the state or managerial concern regarding the scientific education of girls has tended to be limited to a concern about ensuring an adequate supply of scientific and technological personnel. It is not a concern about girls' education as such, but rather with ensuring that the most able girls are creamed off into science and technology.[28] This has had an influence on other initiatives to improve the scientific education of girls simply because state and industry have most often been the funding bodies for affirmative action projects. Thus "manpower" or career concerns are often presented as the chief rationale for introducing positive action into schools to increase the numbers of girls taking science. The second reason that positive action generally takes the form of channeling girls into existing schemes is that it is recognised that any changes science educators would wish to make to the school science curriculum would have to be sanctioned by the examination boards and the universities. However, given the present economic and political context of contemporary science it is unlikely that any radical changes to the present science curriculum - changes which for example embodied a different set of values and incorporated into the curriculum a discussion of the moral and ethical questions which modern developments in science create - would be permitted.[30] Changes to non-examination curricula alone, which, given the current sex-differentiation in science education, would mostly cater for girls, would only serve to reinforce the view that girls cannot do "real" science.

The real contradiction facing science educators now is that school based initiatives which principally aim to increase the number of girls choosing academic science courses which lead to scientific and technological careers will only affect a minority of girls. In their discussion of equal opportunity policy Pratt et al., note that "(school) subjects reflect a structuring of knowledge and impose structures on schools which encourage stereotyped choice because of their associations and implications for pupils of either sex".[31] It is the wider social structure in which schooling is situated which determines this structuring of knowledge. One of the processes involved here is the division of labour which operates "both in regard to paid employment and within the family".[32] Simply channeling girls into subjects which have particular associations with the male adult role does not present equality of opportunity for the vast majority of girls who realistically perceive their future as one primarily concerned with familial responsibilities and "women's jobs".[33]

In the concern to increase the participation of girls in science the state or managerial view has strongly influenced the definition of the problem and the directions in which solutions are to be found. In the attempt to increase the number of girls entering scientific-based careers there has been a manifest failure to consider the more fundamental questions of "what is science education for?", and, "how can it best be included in the education of <u>all</u> pupils?". The failure to consider such questions has led to a restricted definition of the "girls and science" problem as a problem which principally concerns girls. This has meant that "mainstream", male dominated science education has generally been able to ignore the educational challenge that the low numbers of girls in science presents and the status quo prevails. Furthermore, constructing the problem in this way means that once there are no significant problems regarding the flow of new recruits into science and technology, interest in the question of girls and science will quickly fade.

There is a need for an alternative perspective on the "girls and science" problem. The socio-historical perspective of this work has shown that this problem is one which involves much more than the removal of attitudinal barriers to girls' entry into science education. At its very heart the problem involves social and political questions about the place of women in society and about the contemporary role of science. Approaches to the question of the scientific education of girls which ignore this socio-historical perspective are limited in their scope and ultimately serve to disguise the complexity of the issues at stake.

<u>Future research.</u>

In investigating the social shaping of the science curriculum for girls other areas for research have become apparent. Six broad research themes are suggested.

The first concerns <u>the social construction of different versions of science education for girls</u>. One area worth investigation here is the development of science education for girls in the minority of co-educational secondary schools of the early decades of the twentieth century. There is some evidence that in mixed schools there was a more limited choice of science subjects,[34] and in view of the contemporary debate on single-sex education as a factor in science achievement, investigation of this topic could provide useful information. Also, the question of "domestic science" and girls' science education could profit from more extensive treatment than was possible in this thesis. It would be interesting to follow the development of domestic science, or domestic economy education from the 1850s to the present day in the context of science and technical education. In this way it would be possible to map out the influence of domestic science on girls' science education. Also, such work could contribute further to our understanding of the "pure" versus "applied" science debate. Another topic worth investigation under this heading would be the extent of the influence of women's groups such as the Women's Engineering Society and the Electrical Association of Women on the science curriculum in schools, colleges and universities. This would be interesting not only in terms of revealing a specifically female perception of what constituted a good science education, but also in terms of how far the views and rationales of such groups vis à vis science education differed from other, and perhaps competing, professional interest. Finally, little is known at all of the science education for young women in adult and higher education. Chapters two and three offered some insight into the social factors involved in the construction of science education for women in the Mechanics Institutes and for those taking the examinations of the Department of Science and Art. Generally, however, little work has been done on this subject and further research could illuminate factors involved in, for example, the design of alternative syllabuses specifically intended for women.

The second research theme is that of the relationship between rhetoric and reality. By this is meant the extent of correspondence between statements of intent regarding girls' science education and actual classroom and laboratory experiences. This thesis has concentrated on the former in an attempt to show how a particular socio-historical process has operated. The way is now perhaps more open for more detailed work on the actual experience of girls' science education and how this changed over time. Biology and botany education have received little specific attention in this work in spite of the commonly held view that girls' science education historically has been biology or botany. Little direct evidence was gathered on this point both because the concern was to investigate and make visible other areas of scientific education which have been available to girls and because little seems to have been written on this. Certainly, at the level of intentions domestic economy was regarded as the most important form of science education for girls in the nineteenth century elementary schools. In the girls' high schools,with science education finding its place on the curriculum as an important form of intellectual training, the biological sciences appeared to be regarded as less important than physics and chemistry. More detailed work could now investigate for example how, if at all, the broad scope of domestic economy informed the development of biology education for girls in the twentieth century. Furthermore, it would be interesting to discover how far and in what ways biology was regarded as an instrument of education by the high school science mistresses. Given its lower status in science education and its association with girls, a re-evaluation of biology education would be a very worthwhile project. Further investigations are also needed of the content of domestic economy education and the actual science of domestic science by examining text-books, syllabuses and examinations. Similarly it would be useful to know more about the treatment of science for girls in the higher grade schools compared with that for boys, and the treatment of science for women at the teacher training colleges. Investigation of the latter would perhaps illuminate further the science education offered in the elementary education system. In view of the importance of the girls' high school tradition suggested in this thesis, closer inspection of school records, text-books in actual use, laboratory design and apparatus, school histories, oral testimony as well as biography and autobiographies could provide a detailed picture of the reality of the classroom situation.

Related to this second research theme, a third concerns the pupils' perceptions of science education. What did girls think of science education in the 1870s or 1920s? What courses did they choose, what examinations did they sit, what were their aspirations for the future? Did the higher grade schools provide a route to the new universities for working-class girls? Did more girls from these types of school go on to science-related work than girls from the secondary schools? Particular methodological problems are associated with work of this nature. Whilst text-books, syllabuses and examination papers can be located and considered, more problematic is an assessment of the pupils' actual experience of these. The methods of oral history could be employed here, but there are obvious limitations to this type of work.

A fourth research theme encompasses the area of regional and national comparisons. What were the local variations in the provision of science education for girls? Were there significant differences in the content of domestic economy courses, for example, between one region and another? Did the urban/rural difference enter into girls' science education? Did regional differences enter the girls' high schools, or was uniformity maintained by their particular philosophy, or by the influence of external examinations? At the national level, with the necessary attention given to the specific circumstances of each country, it would be interesting to investigate further the relationship of the British domestic science movement to the North American movement; the differences between the establishment of domestic science in Britain and the United States of America and the differences between the professionalisation of domestic science in the two countries.

A fifth theme concerns further investigation of women's relation to the science professions. Chapters two and six demonstrated the marginality of women to the science professions. More research is needed into the question of what scientific fields women entered and why; the barriers that existed; the encouragements - and from whom - that existed. It also needs to be investigated how far women's position in science has actually declined over time.[35]

A sixth and final theme relates to the subject of masculine and feminine approaches to science education. In recent years there has been a growing interest in the differences in cognitive styles between girls and boys and how this might affect choice and achievement in science.[36] There is a need for historical research which can show how far, if at all, there have been alternative views on science which correspond with a feminine cognitive style, and why such alternatives have not survived. Merchant suggests that the investigation of masculine and feminine perspectives in science could proceed by examining the metaphor and symbolism used in science writing.[37] Such research would greatly contribute to a deeper understanding of the development of modern science and its place in contemporary society.

Research into the question of girls and science education from a socio-historical perspective has only just begun. It is hoped that the work presented has opened up new questions, illuminated old ones and suggested some possibilities for the way forward.

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Appendix 1

Schemes of work drawn up by a special committee of the Association of Teachers of Domestic Subjects appointed to consider the teaching of housecraft in secondary schools, 1910.

ELEMENTARY SCIENCE

A - Physics.

Elementary Measurements.

The metric system of measures -
Measurement of length, area, volume, mass and density.

Pressure of the Atmosphere.

The Barometer.

Heat.

The measurement of temperature; thermometers.
Effect of change of temperature on:-
(a) Volume.
(b) State. (Boiling point; Melting point).
Specific heat. Latent heat.
The transference of heat.
(a) Conduction; (b) Convection; (c) Radiation.

B - Chemistry.

Chemical Action.

Examples of chemical changes as distinguished from physical or mechanical change.

(1) Air. Composition of air, the chief chemical and physical properties of oxygen and nitrogen; impurities in the air.

(2) Water. Chemical composition and physical properties of water; its chief constituents. Solution, solubility, distillation, natural waters, hardness of water, storage, contamination, purification.

(3) Common Acids, as hydrochloric acid, sulphuric acid, nitric acid, and their principal derivatives.

(4) Ammonia and its principal salts.

(5) Carbon. Forms of carbon, oxides of carbon, carbonates, chalk, lime. Combustion, flame, Bunsen burner, coal gas.

ELEMENTARY HYGIENE

1. Respiration, difference between inspired and expired air. Ventilation.

2. Food. Relative value under various conditions, e.g., milk, eggs. Micro-organisms affecting the composition of food stuffs. Sterilisation and preservation of foods; meats. Digestion. Function of food.

3. Rest and Exercise. Circulation of the blood.
4. Cleanliness. Clothing.

(The sequence in which this section is taken will be determined by the Mistress of Housecraft).

COOKERY

1. Choice and care of utensils and apparatus used in Cookery.
2. Primary processes used in Cookery - Baking, boiling, frying, grilling, roasting, stewing, etc. These should be illustrated by a well-chosen variety of dishes, including soups, meat, fish, vegetables, savouries, puddings, pastry, bread, cakes.
3. Prices of utensils and materials used in Cookery. Marketing.
4. Choice and preparation of meals.

LAUNDRY-WORK

1. Choice and care of utensils and apparatus used in Laundry-work.
2. Processes used in Laundry-work illustrated by washing and finishing various articles of household and personal use. For example: Under-linen, woollen articles, silks, laces, coloured materials, table linen, bed linen, and household linen generally.
3. Prices of utensils and materials used in Laundry-work.

CARE AND MANAGEMENT OF THE HOUSE (where time allows).

1. Sanitation.
2. Methods of cleaning furniture, rooms, etc.
3. Care of household linen.
4. Method of keeping accounts, inventories, etc.

Appendix 2

Examination paper in domestic science of the Oxford Local Examination Board, 1912.

OXFORD LOCAL EXAMINATIONS, 1912.

SENIOR CANDIDATES

Thursday, July 18, from 6.15 to 7.45 p.m.

Domestic Science

(Write Domestic Science at the head of each sheet of your answers, or you will receive no credit for your work.

No Candidate may attempt more than SIX questions in all.

Answers should be illustrated by diagrams, wherever possible.)

1. A specimen of milk has the specific gravity 1.031 at 15°C. Explain exactly (a) what this statement means, (b) why the temperature is mentioned: describe one way of finding out whether the statement is true. Why is it important to know the specific gravity of milk?

2. The gas in ordinary supply pipes is at a pressure higher than the pressure of the atmosphere. How is this pressure produced? If you wished to measure the pressure how would you do it and how would you express the result? How would you find out whether coal-gas is lighter or heavier than air?

3. Describe as carefully as you can what you observe in an ordinary open fire when a lump of coal is put on it and gradually burns away. How do you explain the various stages of the process?

4. Describe the appearance of washing soda. How does it alter when it is left lying in the air? Why is it called a salt?

Explain as clearly as you can why it is a useful substance.

5. Give an account of the appearance of a starch grain as seen under the microscope. What happens to starch when it is (a) left to stand in cold water, (b) boiled with water? How would you prove that starch contains carbon and hydrogen and that it is closely related to some forms of sugar? How would you prepare some starch from flour?

6. A turnip contains nearly the same percentage of water as milk; how do you account for its hardness? If a turnip is boiled with water it becomes soft; how do you account for the change? If the water in which it has been boiled were filtered off and evaporated in a basin, what result would you expect? What further change would occur if the basin were heated strongly?

7. You are asked to settle the following questions-

(a) which of two kinds of water is the harder;

(b) whether a piece of ice is pure enough for eating;

(c) whether some cayenne pepper has been adulterated with finely powdered brick-dust;

(d) whether a white powder is epsom salts or oxalic acid;

(e) whether plaster of Paris dissolves in water.

Explain what you would do.

8. If a pound of water, a pound of ice, a pound of salt water and a pound of butter were placed in similar dishes on the same hot plate, their temperatures after a short time would be different. Explain this fact as clearly as you can, defining any technical terms which you use in your answer.

If the dishes were kept on the hot plate till the water began to boil, what would you expect to have happened in the other three dishes?

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