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Science and Mathematics Education Centre
Curtin University of Technology

THE GENDER CODE OF SCHOOL SCIENCE

by

LESLEY HANNAH PARKER

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ABSTRACT

This study focused on the relationship between gender and science. The position taken was that this relationship is in need of theoretically informed clarification, from a perspective which allows for the questioning of taken-for-granted assumptions about knowledge. Thus, the sociology of knowledge, a discipline concerned essentially with the ideological basis of knowledge, provided the theoretical underpinnings for the study.

The study's overall purpose was to advance understanding of the gender/science relationship through the development and testing of a theory. Secondary school science, an area in which the problematic gender/science relationship is of particular concern and an area which suffers acutely from lack of theory in this regard, was selected as the specific focus. The problem central to the study concerned the manner in which the structure of curriculum and assessment in secondary schools appears to influence the relationship between gender and science. In addressing this problem, the study involved two major tasks. The first task was to develop a theory which reconceptualises and integrates three strands of previous research, namely, (i) theories about the sociology of knowledge and the school curriculum, drawing initially on the research of Bernstein (1971b), Young (1971b) and Broadfoot (1979); (ii) empirical research, conducted mainly by science educators, concerning the manner in which science curriculum and assessment policy and practice appear to interact with gender; and, (iii) theories developed from the postmodernist feminist critique of science. The second task was to test this theory through a socio-historical analysis of patterns of sex

differences in participation and achievement in secondary school science in one Australian State, namely Western Australia.

The theory of the gender code of school science is the major outcome of the integration of the intellectual and empirical activities described in this thesis. Essentially, it is a conceptual, sociological framework in which gender is a central category. It is shown, in this study, to have both descriptive and predictive power with respect to the gender/science relationship at secondary school level.

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Chapter 1

INTRODUCTION AND OVERVIEW

CONTEXT, PURPOSE AND PERSPECTIVE OF THE STUDY

The relationship between gender and the pursuit of knowledge, particularly scientific knowledge, has been recognised since antiquity and has been the subject of debate for at least six centuries (see Alic, 1986; Schiebinger, 1989). Contemporary studies, especially by feminist historians and philosophers of science (e.g. Bleier, 1984; Harding & O'Barr, 1987; Keller, 1985), have added much to the debate. Some of these (e.g. S. Harding, 1986; Tuana, 1989) have emphasised that, because of the rapidly evolving nature of current thought with respect to the gender/science relationship, the time is not yet ripe to provide definitive answers to the many complex questions which have arisen. In this context, Sandra Harding commented in 1986 that "the present moment is an exciting one in which to live and think, but an inappropriate one in which to conceptualize a definitive overview and critique" (p. 245). Her comment is still valid in 1994.

The research reported in this thesis began, therefore, from the position that the kinds of studies needed in this area are those which seek to clarify understandings of the gender-science relationship, rather than those which seek to provide definitive answers. Its overall purpose, as explained in more detail later in this chapter, was to advance understanding of the relationship between gender and science through the development and testing of a theory. From the

many arenas in which such clarification is necessary, school science, an area where the undertheorisation of the gender/science relationship is particularly marked, was selected as the focus for this study. Following exploration of this area from a sociology of knowledge perspective, the study concluded with the exposition of a new theory. The theory proposes that, effectively, the curriculum and assessment of school science is "gender coded" in ways which act to exclude females from science, especially the physical sciences.

There were three basic premises to the sociological perspective of this study. The first premise concerned the concept of "gender" which, following Sandra Harding (1986, p. 57), was defined as "a fundamental category within which meaning and value are assigned to everything in the world". Gender thus was distinguished from "sex", a term used in this thesis to refer to biological differences between males and females, or to data gathered on the basis of these biologically-based categories.

The second premise concerned the concept of "code". As is explained in more detail in Chapter 2, the term code, in accordance with the more recent work of Bernstein (1990), was taken to mean a way of interpreting the world, which draws attention to the relationship between the power structure of society and the way individuals experience that structure through transmission, acquisition, distribution and legitimation. Bernstein's (1990) definition of a code as "a regulative principle, tacitly acquired, which selects and integrates relevant meanings, forms of realizations and evoking contexts" (p. 101) was adopted as appropriate for the purposes of this study.

The third premise of this study was that the relationship between gender and science is problematic, because of its expression in

human actions which have dysfunctional social and epistemological consequences. The study explored a specific manifestation of the power of the gender-science relationship, namely, the sex-differentiated patterns of participation and achievement in secondary school science.

SUMMARY OF THIS CHAPTER

This introductory chapter presents the background and rationale for the study. It describes the world-wide concerns about the patterns of school science participation and achievement. It then outlines the action taken, especially in Australia, to address these concerns. Highlighting the lack of theory in this area, it leads into the purpose of the study, which, as indicated above, was to enhance understanding of the gender/science relationship, through the development and testing of a theory regarding the gender coding of school science. The chapter then provides a summary of the theoretical background of the study, the methodology, the significance, the definition of the term "gender-inclusive" and the study's specific Western Australian context. It concludes with a brief overview of the thesis.

BACKGROUND AND RATIONALE

Educational Concerns about Gender and Science

In an educational context, concerns about the problematic relationship between gender and science have focused predominantly on the patterns of participation and achievement by females and males in school science. Evidence of these patterns is now

widespread. It has been demonstrated, for example, in the contributions to the seven international GASAT (Gender and Science and Technology) conferences, held biennially between 1981 and 1993. The conference contributions and proceedings cover data from over 30 countries, including both developed and developing countries (Craig & Harding, 1985; Daniels & Kahle, 1987; Haggerty & Holmes, 1993; Lie, 1983; Raat, Harding & Mottier, 1981; Ravina & Rom, 1989; Rennie, Parker & Hildebrand, 1991). In virtually every one of these 30 countries, the participation levels for girls in science beyond the age at which science is compulsory are lower than those for boys. Similarly, although the situation in relation to achievement is less clear than for participation, sex-differentiated patterns of achievement have been reported from large-scale tests of science performance conducted by bodies such as the International Association for the Evaluation of Educational Achievement (IEA) and the National Association for Educational Progress (NAEP) (see Comber & Keeves, 1973; Jones, Mullis, Raizen, Weiss & Weston, 1992; Keeves & Kotte, 1992).

The sex differences reported both in participation and in achievement in large-scale tests vary consistently for different science subjects. In the physical sciences, they are strongly in males' favour, especially in physics. In the biological sciences, differences in participation are in females' favour, while differences in achievement are either slightly in males' favour or non-existent. The situation is somewhat more complex than these patterns suggest, however. There are clear variations across cultures, and a suggestion of systematic variation with socio-economic status. There appear also to be variations according to the type of test or assessment task used to measure science achievement.

These complexities aside, concern regarding the general patterns of science participation and achievement has been expressed with increasing frequency over the past decade. [See, for example, the early work of Kelly (1978, 1981) and later work by Jan Harding (1986), Kahle (1985) and Kelly (1987).] The concern is rationalised from a variety of perspectives related to issues such as social justice, waste of potential and economic necessity (Parker & Rennie, 1989). Whatever the rationale, there is now world-wide concern that, by the end of schooling, there is a much smaller pool of females than of males who are scientifically literate, and who have the motivation and background to progress into further studies in science, into decision-making roles or careers in science and technology, and into activities integral to the application of science and technology in developing countries.

The perspective of this thesis is that the patterns of both participation and achievement in school science are a serious problem, because their effects are far-reaching, for females, for males and for science itself. The pattern of participation results in the under-representation of females in the physical sciences and of males in the biological sciences, with neither sex receiving a balanced education in science, and with the physical sciences continuing to be dominated by a masculine image. The effects of the patterns of sex differences in achievement are also of great significance, because they are linked to perceptions of female capabilities. As is shown later in this thesis, these perceptions do not appear to take account readily of shifts during recent history, and thus they appear to be part of a set of beliefs about achievement, assessment, science and gender, and in a broader sense part of a whole ideology embracing the interaction between gender and science.

This thesis also takes the perspective that these sex differences need to be explored systematically. As Yates (1993) has argued

... not to explore difference is to allow male-constructed knowledge and institutions to remain as the norm, to treat women as 'other' and to concentrate on making women more like men. Without a particular focus on women, it would not be possible to understand the strains they experience in education, nor to evaluate whether the curriculum does them justice.

(Yates, 1993, p. 63)

Addressing the Concerns: The International and Australian Contexts

In recent years, there have been an increasing number of attempts to address the concerns about the nature of females' engagement with science. The considerable effort expended in many parts of the world to make science education more gender equitable is seen, for example, in the contributions to the GASAT conferences referred to earlier. In these contributions and elsewhere in the literature, a wide range of initiatives are described, embracing strategies which aim to produce more equitable outcomes in science through changes in curriculum materials, learning opportunities, classroom climate, student-teacher interactions and career counselling, and in the structure, ethos and organisation of schools.

Until less than a decade ago, Australia was relatively slow to pick up on these concerns about gender and science. The first official Australian documentation of females' educational disadvantage, including mention of science education as an obvious area of inequality, occurred in *Girls, School and Society*, the report of a working party of the Commonwealth Schools Commission (Australia. Schools Commission,

1975). There was little follow-up to this report, however, and little commitment forthcoming from mainstream educational research and science teaching. At the National level, it was not until 1982, when Projects of National Significance were initiated by the Commonwealth Schools Commission, that projects focusing on gender issues in schooling received some support. Science, however, was not regarded as a priority area and much of the \$100 000 made available at that time was allocated to other areas, such as, for example, girls' self esteem. The few science-based projects which were funded received only small amounts. For example, \$8 000 was granted for research into the effect of inservice training on teacher attitudes and primary school science classroom climates (Rennie, Parker & Hutchinson, 1985). Further, although this project was acclaimed and replicated overseas (for example, Kahle, Anderson & Damnjanovic, 1991), it received little recognition or follow-up in Australia. A little later, the science-related recommendations of the second Commonwealth Schools Commission report on the education of girls, *Girls and Tomorrow – The Challenge for Schools* (Australia. Commonwealth Schools Commission, 1984) appeared, at the time of publication and dissemination of the report, to fall on deaf ears.

By 1986, however, the political and economic climate was more receptive to these recommendations. Indeed, the years 1986–1988 witnessed a major change in perceptions of the need to resource gender and science projects and research, frequently in association with recognition of similar needs in the area of gender and mathematics. There appeared to be two major reasons for this change of perception. First, as noted by Yates (1993), because the retention and overall pass rates of females at school level in Australia have been higher than those of males for much of the past decade, "researchers and policy makers have focused heavily on differential patterns...in science and mathematics as

the explanation for girls' inequality beyond school" (p. 33). Second, however, at the Federal level, an increasingly strong science and technology lobby focused on the national interest, and on the nation's alleged need for more and better educated scientists and technologists, and depicted the attrition of able females from science, and from higher level mathematics, as a loss to the nation. This lobbying, in combination with the alignment of the Education portfolio with those of Employment and Training, appeared to bring support for science education and for gender issues in science and mathematics education to the forefront of government consciousness. A number of reports were produced identifying some of the problems with the relationship between gender, science and mathematics, and the need to address these problems (e.g. Hawke & Jones, 1989; Speedy, Annice, Fensham & West, 1989; Willis, 1990).

At the same time, a National Policy on the Education of Girls in Australian Schools (Australia. Department of Employment Education and Training, 1987) was endorsed by State governments. Policy documents and projects at many different levels focused increasingly on science and/or mathematics and gender. A Policy on Girls and Women in Science Education (Australian Science Teachers Association, 1987) and a National Statement on Girls in Mathematics (Australian Association of Mathematics Teachers, 1990) were endorsed by the respective State-based teacher associations. Three major projects addressing gender issues in science/mathematics education were funded: a project to produce girl-friendly and gender-inclusive materials (Lewis & Davies, 1988); a Curriculum Development Centre Project; and a Key Centre for Teaching and Research in School Science and Mathematics (Especially for Women) (Fraser, 1990). These projects are part of what Yates (1993) has identified as a move at the National level to draw together work on the education

of girls across the whole of Australia to make it "more systematic and incremental" (p. 106). While there is still considerable debate about the motives for this approach, irrespective of their underlying motivation, the resourcing of these projects was generous compared to that for any previous activities in the area. Work emanating from them and from the critique which accompanied them (e.g. Franzway, Court & Connell, 1989; Kenway, 1990; Yates, 1991) has provided valuable background for practice and research, including the study reported in this thesis.

The Need for Theorising

Both in Australia and elsewhere in the world, many of the smaller projects addressing gender issues in science education have been carried out by practitioners working in schools or in school systems, as part of what Yates (1993, p. 71) has called " 'commonsense' responses to new concerns about girls and their futures". These practitioners have had little time or incentive to document their work thoroughly, or to provide evaluative or follow-up information. Further, for several reasons, the research of all but a few of the relatively small number of academics working in the area has remained at the level of description and comparison. Thus, although some recent, ongoing work [e.g. Kenway, Willis, Blackmore & Rennie (in press); Leder (1992)] has increased understanding of the way gender and science interact at the school level, much of the effort in this area to date has occurred in a theoretical void. Over a decade ago, Maehr (1983, p. 186) confessed to being "dismayed with the lack of integrating theory in the area of science education and science achievement" and, as noted by Kahle, Parker, Rennie and Riley (1993), little has changed in the past decade to fill the theoretical void.

Although, as is shown in Chapter 4 of this thesis, some theorising about gender and mathematics and some cross-cultural approaches have led to valuable theoretical insights regarding the relationship between gender and science, overall there remains a limited theoretically informed background upon which to base future policy, practice and research. There is an urgent need to develop theories which draw together previous research on gender and science (including empirical research by those working in science education) and relevant paradigms developed by other researchers not directly concerned with gender and science.

Because of their focus on social aspects of the identification and distribution of worthwhile knowledge, and on the social construction of gender, science and achievement, particular paradigms with potential to inform the building of theories about the gender/science relationship are those developed from a sociology of knowledge perspective (e.g. Berger & Luckmann, 1967; Bernstein, 1971a, 1971b, 1974, 1975, 1982, 1990; Mannheim, 1936; Young, 1971a, 1971b, 1973, 1974, 1975, 1976, 1977) and those developed from a postmodernist feminist perspective (e.g. Bleier, 1984; S. Harding, 1986, 1987, 1989, 1993; Keller, 1978, 1982, 1983, 1985, 1989). Traditionally, as noted by Yates (1990, 1993), curriculum theorists and feminist theorists have tended to ignore one another's questions. Thus this study, by synthesising theories from these two sources, together with findings from empirical research, makes a major and original contribution to knowledge in this area.

THE PURPOSE OF THIS STUDY

As stated earlier, the overall purpose of this study was to advance understanding of the relationship between gender and science. The problem central to the study concerned the manner in which the structure of curriculum and assessment in secondary schools appears to influence the relationship between gender and science. In addressing this problem, the two objectives of the study were as follows:

1. To develop a theory which integrates (i) theories about the sociology of knowledge developed by curriculum theorists, (ii) a literature review of empirical research concerning the manner in which science curriculum and assessment policy and practice appear to interact with gender and, (iii) theories developed from a postmodernist feminist perspective on scientific knowledge.
2. To test this theory through a socio-historical analysis of patterns of sex differences in participation and achievement in secondary school science in one Australian State, namely Western Australia.

THEORETICAL BACKGROUND

As implied earlier, the issue which was central to this study (namely, the relationship between gender and science), was defined in social terms, focusing on the patterns of participation and achievement of females and males in school science. These patterns were seen as arising from social actions by, for example, policy-makers, students, parents, teachers and other school-based personnel, within

the context of a specific history and culture. Those social actions, in turn, were seen as influenced by the actors' perceptions of the relationship between gender and science, and their implicit understandings and beliefs about the distribution of knowledge and power in society.

Theoretically, this study was grounded in the sub-discipline of sociology known as the sociology of knowledge. The fundamental premise of the sociology of knowledge – the notion that ideas and beliefs are specific to certain communities and social classes – was held by the Sophists of ancient Greece. Later, the educational implications of this phenomenon were illustrated brilliantly by Weber in his analysis of the "expert" and the "cultivated man" underpinning the education of the Chinese literati in Confucian times (Gerth & Mills, 1948). The sociology of knowledge was first formalised as a sub-discipline in the 1920s in Germany, however, when Max Scheler coined the term "Wissenssociologie". Subsequent to this, it was Karl Mannheim (1936) who introduced this sub-discipline to the English-speaking world. For Mannheim, as for the Sophists, the sociology of knowledge was the discipline which attempted to understand the relationship of beliefs and ideas to the social group and the social situation in which they originate and endure. Mannheim called these beliefs ideologies. He made three major points about ideologies which are especially relevant to the theoretical underpinnings of this thesis: first, it is almost impossible to establish the validity of ideologies by empirical means; second, ideologies arise in specific social settings; and, third, ideologies tend to provide positive support for particular ways of life or for specific groups within the community.

Following Mannheim, and the consolidation of Mannheim's perspective by Merton (1957), the sociology of knowledge grew

significantly with the work of Berger and Luckmann (1967). In developing their famous theory about the social construction of reality, these two sociologists synthesised several theoretical strands from sociology and social psychology. They combined elements from the work of Mannheim, the writings of Marx and Nietzsche, the social psychology of G.H. Mead and the phenomenological approach to reality of Alfred Schutz. Their theory highlighted the "social dialectic" between, on the one hand, society conceptualised as a human product and, on the other hand, society conceptualised as an institutionalised world experienced as an "objective reality" which influences and shapes humanity (1967, p. 79). An essential element of their theory was the passing on of this objective reality from one generation to another, a process involving its "integration" into each individual's experience. Berger and Luckmann (1967, p. 87) proposed that, for integration to be successful (that is, for "institutional meanings to be impressed powerfully and unforgettably upon the consciousness of the individual"), means of "legitimation" are required which take account of meanings that are shared amongst members of a particular social world, and which provide a convincing means for explaining and justifying that world.

Although the theorising of Berger and Luckmann alluded *inter alia* to the school as a secondary socialisation setting, the specific application of the sociology of knowledge perspective to school knowledge was first apparent in a collection of papers edited by the British sociologist M. F. D. Young and published under the title *Knowledge and Control* (1971). Unlike previous work in the sociology of education which had focused on issues of equality of opportunity within a context of economic growth [typified by the text of Halsey, Floud and Anderson entitled *Education, Economy and Society* (1961)], the papers in Young's book were based on the premise that what

counts as educational knowledge is itself problematic. These papers heralded the beginning of a "new direction" for the sociology of education, focused on the definition of worthwhile knowledge and aspects of the distribution of that knowledge, such as the means by which it was distributed and the groups to whom it was distributed.

Two of the papers in that volume, one by Young himself, and the other by another British sociologist, Basil Bernstein, were particularly important to the study reported in this thesis. Together with subsequent work by these authors (Bernstein, 1974, 1975, 1982, 1990; Young, 1973, 1974, 1975, 1976, 1977) and by those who followed them, these papers explored the educational implications of class-related cultural differences. Bernstein and Young generated models to describe the attributes and modes of transmission of school knowledge, and the ways in which various forms of "high status" ("collection code") and "low status" ("integrated code") school knowledge are distributed.

As indicated above, any reference to gender generally is absent from the Bernstein/Young writings. Despite this absence, however, their theorising was fundamental to the present study. As explained in the next section of this chapter, the theory-building undertaken in this study produced a significant elaboration of the Bernstein/Young models, in the form of a theory about the gender coding of school science.

METHODOLOGY

Methodologically, there were two phases to this study – a theory-building phase and a theory-testing phase. The methodology was eclectic and, like the work of Bernstein and Young on which the

study was based, drew on the explanatory power of a variety of approaches. It was also explicitly feminist: as explained in Chapter 3, the study defined gender as a central category for analysing the social world. In addition and, also consistent with its feminist perspective, the study as a whole grew from an intensely personal awareness, developed over many years, concerning the interaction between gender, science and the sociology of knowledge.

The Theory-Building Phase of the Study

In this study, the term theory was defined in accordance with Wiersma (1986, p. 19), namely, "a framework for conducting research (which) can be used for synthesising and explaining...research results". The theory-building phase of the study, which was similar in nature to the exercise carried out by Berger and Luckmann (1967) in the development of their theory about the social construction of reality, consisted of a major synthesis of three strands of previous research.

The first strand concerned the theories developed by the curriculum theorists and sociologists of knowledge, Bernstein and Young, as referred to earlier. In Chapter 2, a detailed critique and reconceptualisation of these theories is presented, with reference also to later work by several other sociologists from the United States, France, the United Kingdom, Australia and Canada. This critique exposed two major gaps in the Bernstein/Young analysis – one concerning assessment and the other concerning gender. The study reported here addressed both of these gaps. In addressing the former gap, concerning assessment, this study demonstrated that the work of another British sociologist, Broadfoot (1979), on the relationship between assessment, schools and society, can be mapped onto the combined, reconceptualised Bernstein/Young model in a way which

enhances the model considerably. In addressing the latter gap, concerning gender, this study drew on the second and third of the three major strands of research referred to above. The second strand concerned empirical evidence, principally from research in science education conducted during the past 15 years, about the relationship between gender and science. The third strand concerned the postmodernist feminist critique of science, which also has been developed during the past decade and a half. This third strand of research, which has exposed the ways in which sexist, classist and racist biases permeate the entire structure of science, also is consistent with the sociology of knowledge tradition (although it is not usually acknowledged as such).

The review of the second strand (Chapter 4) was conceptualised around the work of Kelly (1978, 1985). Focusing initially on the existing explanations for the differential educational experiences of females and males in science, two broad categories of explanations were identified: one premised on the view that the problem lies within females; and the other seeing the situation and conditions in the wider society as the cause of the problematic relationship between gender and science. Within the latter category, the specific focus on the content and process of schooling, including the image of science reproduced in schools, was seen to be of particular importance to this study. The reason for this was that perspectives derived from the latter position provide the most appropriate basis for educational research, policy and action, because these perspectives facilitate a focus on variables which can be *altered* selectively at the system-wide, school or classroom level. From the review of literature concerning interventions premised on this approach, an image was drawn, from a practitioner's perspective, of a more gender-inclusive science. This

image then was interpreted in terms of the reconceptualised Bernstein/Young theoretical framework developed in Chapter 2. The review also revealed two areas which are not well represented in previous research. These areas concern the gender effect of structural, policy-level changes to the curriculum and assessment in individual science subjects at the senior secondary level, and the gender effect of changes in system-wide science curriculum and assessment policy at the senior secondary level. (As described in the next section, these are the two areas which were explored in the theory-testing phase of this study.)

The review of the third strand focused, in particular, on the research of Keller (1978, 1982, 1983, 1985, 1989) exploring the conjunction between science and masculinity and the disjunction between science and femininity. In Chapter 5, Keller's theoretical perspective is reviewed, in the light of the work of other feminists such as Sandra Harding (1986, 1987, 1989, 1993), Hubbard (1989), Martin (1982, 1984, 1985), Schiebinger (1987) and Weinreich-Haste (1986). It is argued that the links between science, masculinity and objectivity, especially in the case of school science, serve to reinforce an image of science which excludes females, particularly from the physical sciences. Further, it is shown that a more inclusive image of science has characteristics similar to the model of low status knowledge generated by Young (1971a) and theorised by Bernstein (1971a) as integrated code knowledge.

The weaving together of these three strands of research led to the generation of the hypothesis that *school science is gender coded in ways which associate maleness with Bernstein's collection code, Young's high status knowledge and high legitimacy because of Broadfoot's formal assessment procedures; and conversely, which associate femaleness with*

Bernstein's integrated code, Young's low status knowledge and low legitimacy because of Broadfoot's informal assessment procedures. Essentially, the research reported in Chapters 6, 7 and 8 of this thesis constituted a testing of this hypothesis.

The Theory-Testing Phase of the Study

Methodologically, the theory-testing phase of the study was in the tradition of socio-historical analyses as undertaken previously, for example, by Layton (1973), Goodson (1983, 1985) and Reid (1985). The rationale for this methodology is described in detail in Chapter 3, noting especially the advantages of this approach and its potential to overcome the empirical elusiveness identified by other researchers as one of the problems with the sociology of knowledge paradigm (Karabel & Halsey, 1977).

The analysis focused in particular on changes in system-wide science curriculum and assessment, and on the apparent impact of these changes on the relationship between gender and science. The changes were explored at two levels, representing the gaps in research identified in Chapter 4: the level of the individual science subject, as described in Chapter 6; and the level of the overall science curriculum, as described Chapters 7 and 8. Through the development and analysis of an extensive data base pertaining to sex differences in secondary school science participation and achievement, the study was able to identify recurring patterns and systematic effects. These patterns provided a meaningful basis for the testing and validation of the theory of the "gender code" of school science developed in the study.

SIGNIFICANCE

The significance of this study is three-fold. First, as explained above, it has considerable theoretical significance, through its development of a new and much-needed theory about the relationship between gender and science. The new theory is shown, in this thesis, to have both explanatory and predictive value in relation to policy decisions about the structure of school science curriculum and assessment. In addition, the integrative process of the theory-building is itself of considerable significance, especially in the context of what Popkewitz (1994) has identified as a critical need for systematic discussions among different intellectual schools of thought in the area of curriculum and policy studies. Like Yates (1993), referred to earlier in this chapter, Popkewitz has noted especially the need for greater understanding of the interrelationship between curriculum studies and recent scholarship in allied fields, including feminist thought. In this sense, this study is part of what Popkewitz (1994, p. 5) would see as a new and enlightening "conversation" between curriculum theory, feminist theory and science education research.

Second, this study has considerable methodological significance, in that it demonstrates a methodology appropriate to the conduct of studies within the sociology of knowledge paradigm. As noted earlier, this has been difficult to accomplish in the past and further, where methodological success within this paradigm has been achieved, it has been mainly through phenomenological studies of schools and classrooms (Karabel & Halsey, 1977). By contrast, the focus of the methodology in this study was on the structural, systemic level, the level identified in much recent research as the one of major future

importance (e.g. Hargreaves, 1989; Shymansky & Kyle, 1992). Indeed, by focusing on this structural level, this study has the potential to inform crucial questions about the future of science education, such as, for example, "*What are the key attributes of effective, systemic curriculum reform?*" (Shymansky & Kyle, 1992, p. 766).

Third, the study also is of considerable practical significance. The pragmatic perspective of the review of previous research in science education (Chapter 4) is of great value. Many previous studies and reviews of the contribution of schools and school systems to the gender/science relationship have been essentially hypothetical. By contrast, this study provides a comprehensive review of features of schools and school systems which apparently do influence the relationship. In this sense, it provides a valuable point of reference for practitioners and policy-makers.

In addition, the theory developed in this study is grounded empirically in Western Australian data pertaining to the effects of a variety of science curriculum and assessment policies. The data base is likely to be useful in its own right. Further, the new theory was developed with the needs of other researchers and practitioners in mind. Thus, it is likely to be useful to future researchers in this area, and also to practitioners committed to eliminating the dysfunctional consequences of the currently problematic relationship between gender and science. It also has the potential to inform decision-making regarding future science curriculum and assessment policies at State and National levels in Australia and, in addition, has application to similar decision-making overseas, for example in some contexts in the United States and the United Kingdom, where a national approach to curriculum and/or assessment is being considered or implemented. In Australia, the need for this kind of

theoretical framework is at present urgent. As indicated in a number of recent documents [e.g. the Finn Report on the post-compulsory education and training of young people (Australian Education Council, 1991)], the broad policy direction of upper secondary education is now set towards inclusion of the whole age group, with particular attention to those who previously might have been disadvantaged because of their gender and socio-economic status. As McKinnon (1988, p. 507) has noted, however, the central task is "to crystallize the structures and approaches through which these ideals will be realized to good effect". That crystallisation process is likely to be both facilitated and informed by studies such as the present one.

THE SPECIFIC CONTEXT OF THE STUDY

Schooling in Western Australia

In Western Australia, students typically spend between 10 and 12 years at school. Most begin their formal education in the year in which they turn six, spending seven years in primary school and between three and five years in secondary school. At the end of their first three years of secondary schooling, students either leave school, or select a program of study for upper secondary school. Typically, students' post-compulsory studies are composed of six subjects and, for most students, these studies lead to an external examination at the end of Year 12. The enforced choice-point at the end of Year 10 has far-reaching consequences and, in this sense, has been labelled a "critical event in the science education of girls and boys" (Parker, 1987, p. 13). Indeed, some of the issues explored in this study related to the existence, nature and timing of the choice-point, particularly insofar as it affects students' education in the sciences, and the relationship between gender and science.

During the first 70 years of this century, the overall secondary school curriculum structure in Western Australia was remarkably stable. For nearly 60 years, dating from 1913, the Public Examinations Board of The University of Western Australia conducted the external examinations taken by all students at the end of Year 10 (the Junior Certificate) and Year 12 (the Leaving Certificate). Change came at the lower secondary level in 1969 when the examinations-based, subject-centred Junior Certificate was replaced by the school-assessed Achievement Certificate, within which science was defined as compulsory for all students, and was operationalised through a multidisciplinary curriculum. A further change, affecting certification and tertiary entrance rather than curriculum as such, occurred in 1975, when the Leaving Certificate was replaced by the Tertiary Admissions Examinations (TAE). In the wake of these changes, there was a further decade of relative stability, until the implementation of the recommendations of two major reports (Western Australia, 1984a, 1984b) known as the Beazley and McGaw reports. Some of the consequences of the changes introduced following these two reports were explored in this study. As discussed in Chapters 7 and 8 of this thesis, the particular focus in this study was on changes in the structure of secondary school science curriculum and assessment, and on the introduction of a Unit Curriculum to replace the Achievement Certificate at Year 10 level, and of the Tertiary Entrance Examination (TEE) to replace the TAE at Year 12 level.

The Changing Upper Secondary School Cohort: Implications for Science

During the decade referred to above (approximately 1975–1985), although the upper secondary school curriculum and assessment structures remained relatively stable, significant changes were occurring

in the upper secondary school cohort. Retention of students into the post-compulsory years of schooling had begun to increase dramatically. For example, of the cohort which entered secondary school in 1955, 19 percent continued on to Year 11 (1958) and 16 percent to Year 12 (1959); in comparison, of the 1980 entering cohort, 67 percent continued into Year 11 (1983) and 41 percent to Year 12 (1984) (Western Australia, 1984b). Thus, by 1984, the upper secondary school in Western Australia contained a group of students which was much larger than that of previous years, and much more heterogeneous in terms of previous achievement, aspirations and destinations. Of this latter group, although only approximately one-third proceeded on to higher education rather than the two-thirds or more of the Year 12 group of a decade before, virtually all students continued to choose a program of study that was made up of six TAE subjects.

The situation described above was recognised as having serious implications for science education, because of the questionable relevance of the then current upper secondary school science curriculum to the changed Year 11/12 cohort of students. Importantly in the context of this thesis, the upper secondary science curriculum in Western Australia, like others in Australia, has fulfilled simultaneously two major tasks – selection and preparation. Traditionally, as noted by Fensham (1985, p. 418) the major science courses both prepare students for higher education and, through the ranking of student achievement in an external examination, also contribute to the sorting and selection of students for higher education. Thus, in Australian education, the role of post-compulsory school science studies in preparing a relatively small proportion of the total student cohort for university science studies always has been clear. Partly for this reason, the better part of the 20th century has seen science education in Years 11 and 12 structured to

replicate the single scientific disciplines offered in tertiary institutions in the early years of the century – typically physics, chemistry, biology and perhaps geology. More recently-developed cross-disciplinary sciences such as biochemistry, microbiology and molecular biology have had little impact on the secondary school curriculum as individual subjects, and at most only selected aspects of these modern sciences have been incorporated in some school biology syllabuses. A feature of most State systems in Australia is that the importance of the traditional, single-discipline subjects, and their links to the tertiary sector, tend to be consolidated through university-dominated syllabus or curriculum committees and examination procedures.

In Western Australia, the suite of seven upper secondary science courses reflects the above situation. Of these seven courses, *Physics*, *Chemistry* and *Geology* are demonstrably the purest in terms of their discipline base, while *Biology* and *Human Biology* are somewhat more multidisciplinary. Also in this latter category is *Physical Science*, a new subject introduced in 1978 in the context of a perceived need for "science-for-all" (discussed in detail in Chapter 6 of this thesis). The seventh subject, *Senior Science*, is a relatively recent introduction into the upper secondary curriculum. Unlike the other six subjects, *Senior Science* is not associated with an external examination at the end of Year 12 and, until very recently, was not supported by a representative Syllabus Committee composed of experts in the area.

Gender Equity Initiatives in Western Australia

Western Australia was not untouched by all of the international and Australian activity in the area of gender equity referred to earlier in this chapter. From tentative beginnings in 1980, with the appointment by the State Education Department of a superintendent in charge of Equal

Opportunity, structural support for equity grew considerably during the next decade. A particular concern of intervention programs associated with gender equity was the underparticipation and underachievement (in some contexts) of females in science and mathematics. A number of projects targeting the widening of girls' subject choices and drawing attention to the occupational significance of demonstrated achievement in mathematics and science were initiated by individual schools, as well as by the system as a whole. The impact of these programs is important to consider in the context of the socio-historical analysis presented later in this thesis.

GENDER-INCLUSIVE: A QUESTION OF TERMINOLOGY

The use of the terms gender and theory in this thesis has been clarified earlier in this chapter. The term gender-inclusive, however, requires some clarification at this point. In 1991, Jan Harding noted with interest that this term, while used commonly in Australia to describe recent developments in the area of gender and science and mathematics education, was not then in use in many other parts of the world. In brainstorming the numerous terms which have been used to describe these developments, she remarked that terms tend to develop historically and to change meaning by taking on various kinds of unforeseen connotations. She pointed out that "if you are wanting to use a term that expresses your purpose, there may be some difficulty in homing in on an exact term" (Harding, 1991a, n.p.). Some similar points were made by Bentley and Watts (1987) in their discussion of the case for "feminist science" and by Weiner and Arnott (1987) in the development of their typology of teacher perspectives on gender and equal

opportunities. They, like Harding, noted the evolution and use, in the UK and to some extent also in the USA, of terms such as the following:

- *equal opportunities*, which was a term that was popular in the 1970s in the UK because of its "fossilisation", as Harding (1991a) called it, by the Equal Opportunities Commission (EOC), but which she saw as less popular in more recent times, because of the EOC's lack of "teeth" and funding;
- *equal access*, which was a term that arose in the UK when it became clear that the existence of the EOC suggested to some that there were no structural, occupational or educational barriers to women;
- *equity*, a term which is prevalent in the USA and which carries with it a concept of something beyond superficial equal access for men and women, something touching on the broader concepts of rights and justice, and equal social, economic and political outcomes;
- *anti-sexist*, a term which Harding (1991a) saw as a more active and aggressive term, with the potential to alienate people, but a term associated nevertheless with valuable and sustained initiatives in at least two UK authorities;
- *girl-friendly*, a term which Harding recalled was used first at GASAT 1 (Raaf, Harding & Mottier, 1981). Harding pointed out that, initially, this term caught people's imaginations. However, as time went on, it became associated with a perception that, for various reasons, science has to be made easier for girls. As a consequence, "girl-friendly" science programs came to be perceived as low status and not very important;
- *gender neutral*, a term which is used frequently by physicists and mathematicians to describe their discipline areas, a usage which has been challenged by feminist philosophers of science during the past decade and a half, as is shown in Chapter 5 of this thesis;

- *gender fair*, which is a term used most often in relation to assessment, where the goal has been to devise "gender fair" (i.e. unbiased) assessment tasks.

What then of the evolution and use of the term gender-inclusive in Australia? Yates (1993) has noted that the initial Australian concern was with *non-sexist* education, involving strategies associated with the liberal view that what was needed was "a common and equal treatment for all students" (p. 77). During the 1980s, however, the term girl-friendly, as defined above by Harding (1991a) came into more common usage, marking a more radical shift to a heightened consciousness that equal treatment for boys and girls in school was inappropriate, because of the deeply gendered knowledge and skills with which they entered school. Also during the early 1980s, the use of the term "inclusive" appears to have been initiated by Jean Blackburn, with her concept of the "sexually-inclusive" curriculum. Blackburn (1982) emphasised that equality between the sexes should be operationalised, in education, in ways which "open up possibilities of a better life for men and children as well as for women" (p. 16). In this context, she pointed out that the real danger of equal treatment of boys and girls was that

[I]t could enshrine traditionally male stereotypes as the human norm in ways detrimental to the very survival of the human race and further elevate the technological above the human in ways which denigrate the basic human tasks with which women have been identified.

(Blackburn, 1982, p. 16)

By the end of the 1980s, although Blackburn's concept of sexual inclusivity had remained intact, linguistically, her term "sexually-inclusive" had been sanitised to become "gender-inclusive". Subsequently, the term gender-inclusive was cemented into place,

especially in science and mathematics education, by the extensive work of the McClintock Collective in the Australian State of Victoria (e.g. Gianello, 1988). Even this term, however, has undergone change during its relatively short life. As defined by Hildebrand (1989) it focused almost exclusively on girls and women – their need for control over the science and technology in their daily lives, and the need for them to be valued as contributors to science and technology, and to enter science-related careers. Perhaps not surprisingly, this definition was associated with strategies which were very like girl-friendly science (Harding, 1991a). They appeared to make it easier for girls to be involved in science, but did little for boys' science education, which continued to be depicted and practised in rather negative, traditional terms. Increasingly, however, it is being realised that boys, too, need to learn a science which is "more people and community orientated" (Hildebrand, 1989, p. 7). As Harding (1991a) pointed out, the ways in which we value what both boys and girls bring to science classrooms, and work towards both sexes acquiring an image of science which embraces all human beings, need to be explicit in our definition and our practice of whatever this alternative science is. For all of these reasons, gender-inclusive is the preferred term of this thesis. Arguably, of all the terms used to date, gender-inclusive is the one which captures best the attributes of the kind of science education which will improve the experiences of both girls and boys.

SUMMARY: OVERVIEW OF THE THESIS

This introductory chapter has outlined the major elements of the study: its background and rationale, purpose, theoretical framework, methodology and significance. It has presented also a description of the specific context of the study, secondary school science education in

Western Australia during the years 1969–1992, and it has clarified the use of the term gender-inclusive. Following this chapter, Chapter 2 presents a critique of the work in curriculum theory of Young and Bernstein and develops the initial theoretical framework for the study. Chapter 3 then describes the methodology for the study. Chapter 4 presents an overview of various perspectives on sex-related differences in science and a detailed review of research demonstrating ways in which features of schools, school systems and of science itself appear to influence the problematic relationship between gender and science. It also builds an image of a more gender-inclusive science and maps this image on to the initial theoretical framework produced in Chapter 2. Chapter 5 then reviews the feminist critique of science, focusing especially on the work of Keller (1978, 1982, 1983, 1985, 1989) and producing again an image of a more gender-inclusive science, this time from a theoretical perspective. Again, this image is mapped on to the initial theoretical framework of the study.

Moving to the more empirical, theory-testing aspects of the study, Chapter 6 presents an analysis of the links between gender and the concept of science-for-all, with specific reference to the gender issues which emerged during the implementation of a science-for-all type of curriculum at senior secondary level in Western Australia. Chapter 7 then focuses in detail on the lower secondary school science curriculum operating in Western Australia between 1969 and 1987 and the upper secondary school science curriculum prior to 1986. It analyses the implications of the structural changes which occurred for the relationship between gender and science. Chapter 8 presents a further analysis in the context of major structural changes to curriculum and assessment at the upper secondary level which occurred in 1985 and first impacted on Year 12 students in 1986.

Finally, Chapter 9 presents a summary of the whole study and a synthesis of its outcomes, arguing that the socio-historical analysis reported in Chapters 6–8 provided generally strong support for the gender code theory developed in the first phase of the study. The thesis concludes with a personal reflection and evaluation, focused on the methodological decisions taken as part of the study. This personal evaluation addresses, in particular, issues pertaining to the validity, generalisability and limitations of the study and, in addition, highlights the study's implications for future research and practice.

Chapter 2

INITIAL THEORETICAL FRAMEWORK: KNOWLEDGE AND CONTROL

INTRODUCTION

The purpose of this chapter is to report the development of the initial theoretical framework which guided this study. As indicated in Chapter 1, this initial framework was developed from research emanating from the "new" sociology of education, specifically the work of the British sociologists Bernstein (1971a) and Young (1971a). These two researchers linked their work conceptually to earlier theorising in the sociology of knowledge (e.g. Mannheim, 1936), and acknowledged their debt to some of the so-called founding fathers of sociology such as Durkheim and Weber. Part of their unique contribution, however, concerned their explicit focus on school knowledge. They began by questioning the taken-for-granted assumptions about the nature of worthwhile school knowledge and the kinds of students to whom this worthwhile knowledge is distributed. They were concerned especially with the relationship between the stratification of knowledge into high and low status forms, and the stratification of society into upper and lower classes of people. They attempted, in a sense, to relate the problem of unequal outcomes of schooling for specific groups in society to that of "socially controlled cultural transmission" (Karabel & Halsey, 1977, p. 44). School knowledge was seen as symbolic property and "cultural capital" (Bourdieu & Passeron, 1977), and education systems and schools were

seen as preservers and distributors of this symbolic property or cultural capital, and thereby as reproducers of some important aspects of inequality.

As noted by Apple (1979), typical analyses based on this approach have three dimensions: the school as an institution, the educator (and her/his interactions with the learners), and the knowledge forms. Each of these dimensions is "situated within the larger nexus of relations of which it is a constitutive part" (p. 3). The major focus of this chapter is the third of Apple's dimensions, the knowledge forms. The chapter explores theories and research bearing on the definition and distribution of these knowledge forms, and their contribution to class-based hierarchies in society. Where relevant to the central argument, the discussion includes also reference to some aspects of the role played in socially-controlled cultural transmission by the other two of Apple's dimensions, school organisation and teacher-student interaction. It should be noted, however, that detailed analyses of these from a sociology of knowledge perspective can be found elsewhere [for example, the research of Tyler (1988) and Daniels (1988) on school organisation, and that of Cooper (1976) and Delamont (1983) on classroom interaction].

The first sections of this chapter provide a critical review of some of the fundamental contributions of Bernstein (1971a, 1971b, 1974, 1975, 1982, 1990) and Young (1971a, 1971b, 1973, 1974, 1975, 1976, 1977) to the sociology of the curriculum, emphasising the theoretical frameworks developed by these researchers, and integrating and reconceptualising these frameworks in a diagrammatic form. The chapter then discusses two strands of research in the tradition of the new sociology which are of particular significance to this study. These concern, first, the stratification of school knowledge, and second, the crucial role of assessment. The discussion of stratification is essentially of a confirmatory nature in

relation to Bernstein/Young theoretical frameworks. The discussion of assessment, while also confirmatory of the Bernstein/Young frameworks, emphasises the importance of including assessment as a fundamental and thoroughly explicated component of these frameworks. It demonstrates also that the frameworks are enhanced considerably by the addition of a dimension derived from Broadfoot's (1979) typology of formal and informal modes of assessment. The chapter then concludes with a summary of the theoretical position which provides a foundation for the remainder of this study.

BERNSTEIN: A THEORY OF CLASS, CODES AND CONTROL

The Scope of Bernstein's Research: The Concept of "Code"

Bernstein's research has spanned nearly 40 years, beginning when he was a teacher of a variety of subjects to predominantly working class students at the City Day College in London (UK) and continuing to this day from his position as a retired Professor at the University of London Institute of Education. During his career, he has been responsible for two major developments in the sociology of education. The first was a theory of class relationships and educability based on socio-linguistics. This theory was developed partly from empirical data, partly from scholarly reviews of the literature and partly from Bernstein's own theoretical explorations and his work on a language program for infant schoolchildren. The second was a model for analysing educational systems in terms of the transmission of educational knowledge. This work was more theoretical than his earlier work. As noted by Danzig (1991), it is considered by some to be one of the seminal contributions in the sociology of education. The study reported in this thesis drew on this second area of Bernstein's research.

In considering Bernstein's work, it is important to clarify the definition of "code" that he developed, especially as the term code is fundamental to this thesis. In practice, he took many years to define the term satisfactorily. This is particularly confusing in the literature, because many writers do not seem to appreciate that the codes of what might be called the first wave of his research (the "restricted" and "elaborated" language codes) are rather different from the codes of the second wave (the "collection" and "integrated" knowledge codes), which differ again from the codes of the third, when he identifies more explicitly with a cultural reproductionist perspective [as in, for example, his treatise on codes, modalities and the process of cultural reproduction, in Apple (1982)].

Bernstein himself clearly appreciated this problem. In a postscript to the 1971 revised edition of *Class, Codes and Control* (Vol.1) he presented a series of definitions of code which he claimed represented the evolution of the concept. Subsequently, since 1981, he has tended to see a code as "a culturally determined positioning device" (1982, p. 305). Consistently since that time, he has defined a code as "a regulative principle, tacitly acquired, which selects and integrates (a) relevant meanings, (b) forms of their realization, (c) evoking contexts". This definition is satisfactory for the purposes of this thesis, particularly given its emphasis, in Bernstein's terms, on "the *interaction* between transmitters and acquirers and their controls" (1990, p. 130).

Bernstein's Concept of the Social Basis of Knowledge

One of the major springboards for the theoretical explorations pursued in this study was Bernstein's paper *On the Classification and Framing of Educational Knowledge* (1971a) in which he developed a model for analysing educational systems in terms of the social basis of

knowledge. This model entailed three levels of analysis, which related to, first, the three "message systems" (curriculum, pedagogy and evaluation), through which formal educational knowledge is realised; second, the concepts of "classification" and "frame" which were used to analyse the structure of power and authority underlying the three message systems; and, third, the concept of educational knowledge codes, termed the "collection code" and the "integrated code", through which the principles of power and social control are mediated and through which the consciousness of individuals is shaped.

The message systems

In Bernstein's model, curriculum, pedagogy and evaluation were the social entities through which the reality of educational knowledge is constructed. His definition of these three message systems was as follows:

Curriculum defines what counts as valid knowledge, pedagogy defines what counts as a valid transmission of knowledge, and evaluation defines what counts as a valid realization of this knowledge on the part of the taught.

(Bernstein, 1971a, p. 47)

In the typical interpretative mode, these message systems were not specified in absolute terms. For example, curriculum was not equated unquestioningly with valuable or valid knowledge, but with *what counts as valid knowledge*. Clearly the judgment about whether or not certain knowledge is valid does not just happen. It is made by people, and moreover by people in a specific context, people who bring to their decision-making sets of attitudes and knowledge acquired throughout their lives. It is made, for example, by people such as those on subject Syllabus Committees in Western Australia.

The concepts of "classification" and "frame"

As indicated earlier, Bernstein used the concepts of classification and frame to analyse the structure of the three message systems, curriculum, pedagogy and evaluation.

Classification. Classification referred essentially to the degree of boundary maintenance between the contents of the curriculum (1971a, p. 49). A strongly classified subject emerged as one which has distinct boundaries, and is pure in the sense of being a specialised single discipline. Bernstein saw a strongly classified subject as based on difference from, rather than communality with, others, and therefore as inducing a strong sense of class membership and identity in students who study it (1971a, p. 51).

Bernstein's concept of classification can be applied readily to the subjects in the upper secondary school science curriculum in Western Australia. For example, scrutiny of the syllabus statements in use during the period of this study (e.g. Western Australia, Secondary Education Authority, 1990) reveals that *Physics*, presented as a relatively pure, single discipline (p. 345) would be categorised as strongly classified. Similarly, *Chemistry* and *Geology* also are presented as relatively pure disciplines and, although there is some emphasis in the former on "important uses" and "industrial processes of major local and world-wide significance" (p. 321) these subjects, too, would be categorised as strongly classified. The biological science subjects, however, are much less strongly classified. The syllabus statement for *Biology* refers specifically to application to "areas of personal and social concern" (p. 313), while *Human Biology* is described as "a multidisciplinary study of humans at the levels of populations, individuals, systems, tissues and cells" (p. 333). *Senior Science* is described as an even more multidisciplinary subject, covering a "a wide view of science" including some areas "not treated in traditional

school science courses" (p. 357). Thus it would be categorised as very weakly classified.

In relation to power, strong classification was portrayed by Bernstein as reducing the power of the teacher over what is taught. This is partly because strong boundaries by definition inhibit stepping beyond the prescribed content and processes of the curriculum. It is also associated with the exercise of power by the boundary maintainers or guardians of the discipline in a strongly classified subject. In this respect it is significant that, as indicated in Chapter 1, the very weakly classified subject *Senior Science* did not have, until very recently, an appointed set of guardians, in the shape of a fully constituted Syllabus Committee.

Frame. The issue of power and where it lies links the concept of classification to the second of Bernstein's pair of concepts, the concept of frame. In Bernstein's model, frame referred to the context in which knowledge is transmitted, received and evaluated. In particular it referred to the degree of control that the teacher and pupil have over the organisation, pacing, timing and physical arrangements associated with the transmission of knowledge, and the degree to which these processes are close to or remote from everyday community behaviours. A strongly framed subject emerged as one in which the teacher, usually as the agent of the system, has power in the pedagogical teacher-pupil relationship, and one in which the teaching-learning processes are structured and conducted in a very formal, detached manner, which insulates them from everyday life and commonsense, community processes and perceptions.

Again, with reference to the Western Australian upper secondary science curriculum, the pedagogy associated with *Physics*, described by Parker and Rennie (1993, p. 2) as exemplifying "a received curriculum, with an emphasis on ... routine numerical exercises, contexts which are

unfamiliar to students and disembodied theory" would place it as a strongly framed subject. Similarly, the pedagogy associated with *Biology, Chemistry, Geology, Human Biology* and *Physical Science*, although including some emphasis on community issues, is relatively formal, as for all externally examined TAE/TEE subjects. Thus they, too, are strongly framed subjects, although perhaps not as strongly as *Physics*. The pedagogy associated with the school-assessed subject *Senior Science* is, by contrast, very weakly framed. For example, in the 1990 SEA Syllabus Manual, schools are encouraged "to choose the content and learning experiences that best suit the needs of their students" and are reminded that "community and the local environment should be considered as part of the learning environment" (p. 358).

Summary. In Bernstein's model, as explained to this point, the concept of classification relates to what is taught and that of framing relates to how it is taught. Thus, just as classification is concerned with content, framing is concerned with process. And while the strength of classification determines the structure of Bernstein's curriculum message system, the strength of framing determines the structure of his pedagogy message system. This theoretical framework is presented diagrammatically in Figure 2.1. The framework at this stage begs the question of the place of the third of Bernstein's message systems, evaluation. In Bernstein's model, this was presented rather loosely as a function of both classification and framing, with both the content and the processes of educational transmission being integral to it. This third message system was not explored by Bernstein in any depth, however, thus leaving a major gap in his initial model. As is shown later in this chapter, an important contribution of this study was the elaboration of Bernstein's model to include an explicit focus on assessment as the means of legitimation.

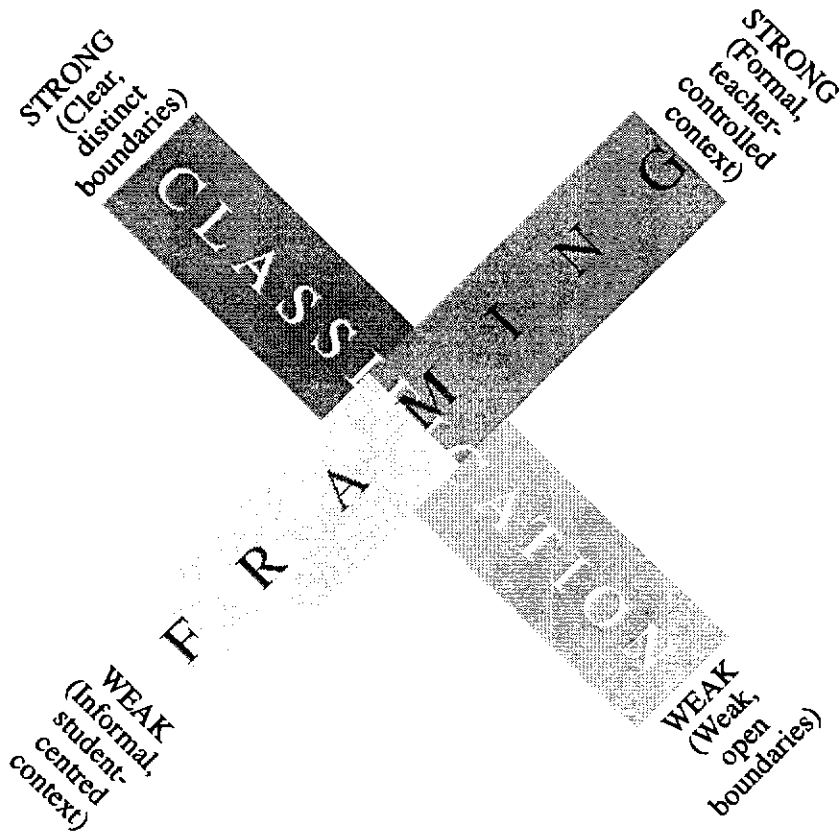


Figure 2.1. Diagrammatic representation of Bernstein's model of classification and framing.

Educational knowledge codes: the "collection code" and the "integrated code"

Having defined the fundamentals of his model, Bernstein went on to distinguish between two broad types of curriculum – the collection code in which the classification and framing are strong (as in the example given previously of *Physics*), and the integrated code in which the classification and framing are weak (as in *Senior Science*). This kind of clearcut dichotomy between collection code and integrated code appears to leave subjects such as *Human Biology*, *Biology* and *Physical Science* (which are weakly classified but strongly framed) in an intermediate,

undefined position. To some extent, this problem was solved by Bernstein (1977, 1982). In some notation used in his application of code theory to the processes of cultural reproduction, he used the simple device of positive and negative signs to designate degrees of classification and framing. For example (+C) indicated very strong classification and (-C) weak classification. Although this notation was not intended to apply to school subjects, it is nevertheless useful, in the context of this thesis, to be able to refer to mixes of classification and framing which are outside the boundaries of pure collection code or integrated code subjects. For example, *Human Biology* can be represented as (-C)(+F). With these provisions in mind, it is possible now to add the concepts of collection code and integrated code to the initial diagrammatic representation of the model in Figure 2.1. The modified diagram is shown in Figure 2.2.

In discussing his theory of knowledge codes, Bernstein proposed that

...where knowledge is regulated by collection codes, social order arises out of the hierarchical nature of the authority relationships, out of the systematic ordering of the differentiated knowledge in time and space, out of an explicit, usually predictable, examining procedure. Order internal to the individual is created through the formation of specific identities. The institutional expression of strong classification and framing creates predictability in time and space.

(Bernstein, 1971a, p. 63)

Bernstein depicted the ideological basis of the collection code as tacit – a condensed symbolic system, communicated through accepted, boundary-maintaining features, such as the Syllabus Committees in the Western Australian system. The ideological basis of the integrated code,

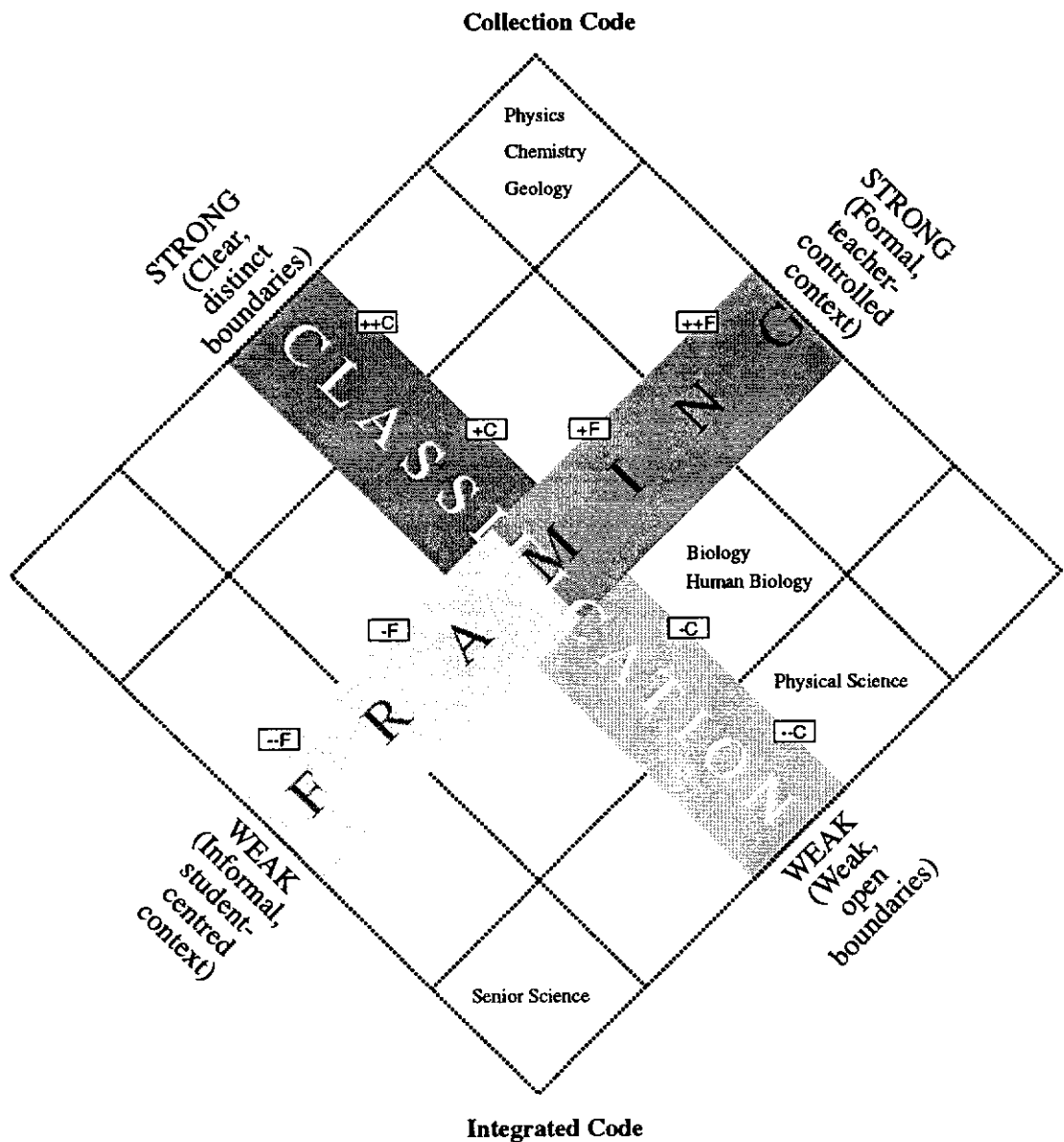


Figure 2.2. Diagrammatic representation of Bernstein's model of collection code and integrated code, showing positions of upper secondary school science subjects in Western Australia.

by contrast, was depicted as explicit, but resting upon weak boundary-maintaining features. In both cases, Bernstein argued that his concept of boundaries to the content and processes of the curriculum revealed both the power dimension and the control dimension of the selection and transmission of educational knowledge. As is explained in the next section, these aspects of power and control also were explored by Young

(1971a), whose work is linked both historically and substantively with that of Bernstein.

YOUNG: CURRICULA AS SOCIALLY ORGANISED KNOWLEDGE

Background

As indicated earlier, Michael Young was the editor of *Knowledge and Control* (1971a), the reader which is recognised as a watershed in the sociology of education. While his early work did not refer explicitly to knowledge codes, his paper (1971b) outlining an approach to the study of curricula as socially organised knowledge is highly relevant to the arguments and theory developed in this thesis. Young defined "what counts as educational knowledge" as problematic (1971a, p. 6). Like Bernstein he focused on the curriculum offered in schools and on the content, pedagogy and, to some extent, the assessment associated with its transmission. Also like Bernstein, much of his work was highly theoretical, containing, but not exploring suggestions for empirical validation of his theories.

Given the concern of this thesis with the science curriculum, the perspective which Young brought to bear on the sociology of education is of more than passing interest. He began his professional career as a science teacher, moving from there into teacher education and educational research at the University of London Institute of Education. In 1971, at the time of editing *Knowledge and Control*, Young was acutely conscious of "government pressure for more and better technologists and scientists" and the alleged "swing from" science (1971b, pp. 20, 21). In his writings, he argued strongly that perceptions of these needs and problems depends very much on the social definitions of science, i.e. on what does and what does not count as "science" and, further, that these social

definitions vary throughout history, across different cultures and in different situations within a single culture. He argued that

... once the meanings associated with 'science' and 'technology', and 'pure' and 'applied', are seen as socially determined, not only does it become possible to explore how these social meanings become part of the school context of pupil preference, but a sociological enquiry into the intellectual content of what counts as science becomes possible.

(Young, 1971b, p. 21).

The aspects of Young's research which impinge on "enquiry into the intellectual content of what counts as science" are explored in Chapter 6 of this thesis, in the context of an analysis of syllabuses which purport to be "science-for-all". This present chapter is concerned with the more general aspects of Young's argument, related to the stratification of school knowledge.

The Relative Status of School Subjects

Young's major concern is with the relationship between, on the one hand, the relative status of school subjects and, on the other hand, the nature of their content and learning opportunities (and, to some extent, also their assessment procedures), together with the ability range and social class of students who study them. His emphasis was on the process by which certain school subjects come to be perceived as more worthwhile than others and to be selected and studied by certain students on the basis of these perceptions. Specifically, he claimed that the dominant characteristics of high-status knowledge are

... *literacy*, or an emphasis on written as opposed to oral presentation; *individualism*, or avoidance of group work or cooperativeness, which focuses on how academic work is assessed and the characteristics of the 'process' of knowing and the way the

'product' is presented;... *abstractness* of the knowledge and its structuring and compartmentalizing independently of the knowledge of the learner; ... and ... *unrelatedness* ... which refers to the extent to which (it is) "at odds" with daily life and common experience. (Italics added)

(Young, 1971b, p. 38)

He argued also that access to and choice of such high status knowledge tends to be limited to students whom the teacher defines as the most able. In other words, there is a situation in which knowledge which is perceived as most worthwhile is studied predominantly by students who are perceived as most worthwhile.

He hypothesised that a ranking of curricula on each of these four dimensions would reveal that academic curricula are "abstract, highly literate, individualistic and unrelated to non-school knowledge" (p. 38) and that, by contrast, curricula labelled as non-academic would be "organised in terms of oral presentation, group activity and assessment, concreteness of the knowledge involved and its relatedness to non-school knowledge" (p. 38). He saw these characteristics as socially defined and therefore problematic, because their persistence is due to conscious and unconscious cultural choices made by human beings, choices which "accord with the values and beliefs of dominant groups at a particular time" and which define the parameters of educational success and failure.

With reference to the British education system, Young argued that academic curricula involve assumptions that some kinds of knowledge are more worthwhile than others. In Mannheim's (1936) terms, as explained in Chapter 1, these assumptions can be seen as ideologies, because they sustain the values, power and privilege of specific groups. Young argued also that changes to academic curricula will be tolerated only to the extent that they do not undermine this set of values, power and privilege. As is shown in Chapter 6 of this thesis, Young's arguments

were quite prophetic in relation to the fate of alternative science subjects introduced in various parts of the world during the past decade or two.

Analogies between the Positions of Young and Bernstein

The analogies between the positions of Young and Bernstein are clear. As shown diagrammatically in Figure 2.3, Young's "high status knowledge" is essentially Bernstein's "collection code" and Young's "low status knowledge" is Bernstein's "integrated code". These two pairs of constructs are fundamental to theories about the ways in which the education system converts social hierarchies into academic hierarchies. Further and, although neither Bernstein nor Young demonstrated this empirically, these academic hierarchies then act to legitimate and perpetuate the social hierarchies and the social stratification from which they were derived.

The combination of Young's and Bernstein's models was of particular interest to this study in two ways. The first way concerned the issue of the "abstractness" of high status, collection code knowledge. In Western Australia, in the case of *Biology* and *Human Biology*, the syllabus statements for the two subjects suggest that both have relatively weak classification (in Bernstein's terms). However, the research of Sydney-Smith and Offer (1991) indicates that *Biology* is perceived by teachers and students to be more abstract and conceptually difficult than *Human Biology*. Thus, in terms of the Bernstein/Young combined model, *Biology* would be placed more towards the strong end of the classification continuum than *Human Biology*, as shown in Figure 2.3.

The second way in which the combined model was especially important to this study was that it suggested that strong classification is a prerequisite for the stratification of knowledge. In this sense, the division of school knowledge into separate, clearly-defined subjects (from amongst

which students choose, with varying degrees of freedom, a total program of study), is fundamental to the stratification of knowledge in schools. Thus, indirectly, "greater subject choice" can be seen as a further characteristic of strong classification.

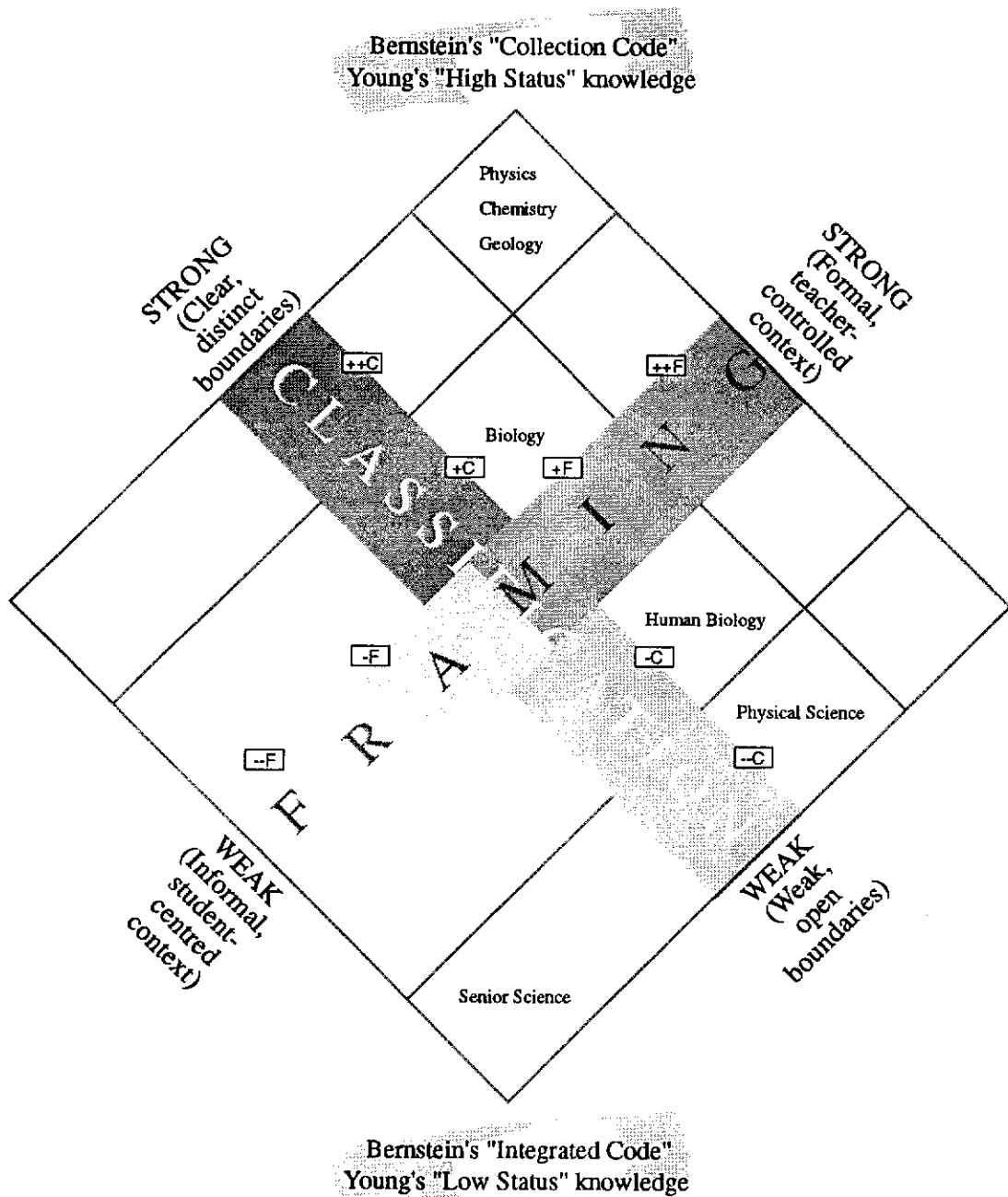


Figure 2.3. Reconceptualisation of the Bernstein/Young models, showing the revised positions of upper secondary school science subjects in Western Australia.

NEW DIRECTIONS OR "KNOWLEDGE OUT OF CONTROL"?

The work of Young and Bernstein sparked many years of vigorous debate, characterised by extremes of response from other sociologists and philosophers. Some have argued that the Bernstein/ Young work was highly creative. Bernstein, for example, was described by Jackson (1974) as the best known creative sociologist in Britain and as "arguably the most influential ... in his impact on educational curricula" (p. 65). Others, however, have deemed their work difficult, complex and contradictory, as well as being at times repetitive, rambling and saturated with jargon.

Much of Bernstein's work, in particular, has been controversial, to the extent that Davies (1994) has characterised it recently as generating "universal hostility" (p. 9). Even by some of its supporters, it has been described as ambiguous and self-contradictory (Reid, 1978, p. 182). Indeed, Jackson (1974) argued that, between 1965 and 1971, Bernstein reversed the central claim of his own theory of class relationships and educability. Others (e.g. Mackinnon, 1976, p. 23) have criticised his work as highly speculative, based on small samples and encompassing a narrow range of criteria. Yet others, such as Karabel and Halsey (1977, p. 64), have described it as "plagued by a certain empirical elusiveness"; while Sharp (1980, p. 45), from a Marxist perspective, highlighted the "shortcomings" of the "theoretical underpinnings of his work"; Stubbs (1983) described his explanations for the educational disadvantage of working class children as inadequate and focused too much on changing the children rather than their schools; and King (1978, 1979) argued that Bernstein's concept of "invisible pedagogy" is "vacuous", "misleading" and unsupported by empirical evidence.

As part of what has been called by Bates (1980, p. 67) a "trenchant and unsympathetic critique", Pring (1972) developed a particularly cutting

critique of the new sociology, which he published as a paper entitled *Knowledge out of Control*. In Pring's view, the new sociology, especially the work of Young, was flawed because of extreme social relativism. Pring objected to a view of knowledge which removed its "autonomous and sacred character" (1972, p. 129). He suggested that, in pronouncing on the nature of knowledge, most of those who were part of the new movement were raising and answering philosophical questions, but failing to understand what sort of questions they were raising, or what was involved in such procedures. He envisaged teachers, confronted with the new sociology, "quaking before the prospect of sociohistorical relativism" and forgoing "their educational ideals and their instructive role" (1972, p. 133).

Both Young and Bernstein have gone to considerable trouble to refute these kinds of criticisms, as seen, for example, in Young (1974) and Bernstein (1990). In particular, Bernstein (1990) argued that the criticisms were based on misinterpretation and incomplete readings of his work – a position which in itself is perhaps an indication of the complexity of his theorising and writing. This complexity poses both a problem and a challenge – as Davies (1994) has noted, even today, Bernstein's "complex and still evolving analyses of education have not yet been fully appreciated or understood" (p. 9).

Despite this situation, however, many sociologists have been strong in their defence of the new sociology of education. Bates (1980) argued convincingly in its favour, in terms of its epistemological and ideological soundness and its capacity to improve educational practice through the processes of critical reflection and innovation. At a broader level, the analysis of Whitty (1985) has shown that Young and Bernstein had a tremendous impact on subsequent developments in sociology and curriculum theory. As Smith (1988) has commented, serious students in

the area "need to traverse the terrain of the 'new' sociology of education if they are to comprehend contemporary work and the conditions of its existence" (p. 489).

Bates' and others' support for the new sociology of education appears to have been well-founded. Many years on, the seminal influence of the new perspective on sociological analyses, including that conducted in this study, is still apparent. As foreshadowed by Bates, this approach has the capacity to provide, amongst other things,

(i) a coherent epistemology related to the ideas of critical social theory whose justification is by appeal to the criterion of human betterment, (ii) a systematic analysis of social, economic, cultural, epistemological and educational hierarchies and their interpenetration...

(Bates, 1980, p. 77)

It is these kinds of hierarchies which are the topic of the next section, focusing on research into the stratification of school knowledge.

THE STRATIFICATION OF SCHOOL KNOWLEDGE

Basically, the position which developed from Bernstein's and (especially) Young's challenges to taken-for-granted assumptions about the school curriculum was that the stratification of school knowledge serves the interests of social, cultural, economic and academic elites. Empirically, this was demonstrated by research such as that of Keddie (1971) who found that teachers' academic expectations of pupils in lower ability streams were based mainly on perceptions of their social class, and that, in association with this expected link between social class and intellectual ability, these students actually were excluded, in an ongoing

way, from access to high status knowledge, which remained the preserve of the high socio-economic status students.

The contributions of Bourdieu (1976) and Apple (1979, 1982) also were fundamental to the development of this position. Bourdieu's theories were based on the concept of cultural capital. In terms of schools and students, the kind of cultural capital inherited by students of higher socio-economic levels was seen, because of the way knowledge is stratified by schools and school systems, as putting high socio-economic status students in a favourable position to accumulate what is defined as high status knowledge during schooling, and thus to consolidate their elite status. Apple (1982) developed this point even further, arguing that high status knowledge in schools is itself determined in part by established economic interests, and thus, that high status knowledge during this century has emerged as high status *technical* knowledge. Similarly, Broadfoot (1979, p. 131) pointed out that worldwide, in both developed and developing countries, the content and the processes of what is seen as worthwhile education are reflecting, increasingly, technological imperatives.

Apple's arguments, taken together with some of Young's later writings specifically on school science, are particularly relevant to the concerns of this thesis. In a sophisticated variant of the "critical filter" argument (Sells, 1976), Apple (1979) has noted that, in schools, high status technical knowledge "is used as a device or filter for economic stratification" and that "socially accepted definitions of high status knowledge preclude consideration of non-technical knowledge" (p. 382).

Collins (1989) also explored these kinds of issues, specifically in relation to the Australian upper secondary school curriculum. She discussed the long traditions of the academic curriculum in Australia, highlighting themes which are strongly reminiscent of Young's

definition of high status subjects, themes such as independent enquiry and argument; written language, logic and mathematics; a strong theoretical base and an emphasis on the abstract; and a separation of the academic from the applied and the practical. Collins' analysis of the nature of the Australian academic curriculum at the beginning of the 1990s was particularly relevant to this study. She indicated that, although it consists of

... the positivist science variant of the theory/abstraction tradition, plus a basic skill, plus some preparation for rising white-collar employment...*the highest prestige is attached to doing well in the positivist heartland.* Mathematics, as the language of positivism, and physics and chemistry, taught as the most theoretical and cut-and-dried sciences, constitute that heartland. The place of highest esteem is given in Australia, not to the student who can speak three foreign languages (probably an immigrant), nor to the student who topped accounting (could be an upstart), nor to the student with great insight into literature (probably a 'girl'), but rather to the double math/physics prize winner, seen as representing the peak of human intellectual competence. (Italics added)

(Collins, 1989, p. 16)

Thus, in Australia, as in many other countries, the academic, subject-based curriculum is traditionally the hegemonic curriculum. The research of Hargreaves (1989) in relation to Britain, together with that of, for example, Larabee (1986) relating to the United States, and Tomkins (1986) relating to Canada, has demonstrated this tradition clearly. Hargreaves has shown, for example, that at least up until the late 1970s, this kind of curriculum was accepted "publically, politically and professionally" as "the most highly prized form of educational knowledge in society" (1989, p. 62). Many, like Collins (1989), would maintain that this is still the case.

These ideas connect also with those voiced in other writing about school subjects. Goodson (1992), for example, emphasised that school subjects "play their part in preserving entrenched social divisions" (p. 4). Taking a social reconstructionist approach, which he acknowledged owed an "enormous debt to Bernstein" (p. 5), he argued that school subjects are constructed by "subject communities". Following Kliebard (1986), Goodson characterised the school subject in the British, American and Australian high school curriculum as "an impregnable fortress" (1992, p. 24). He depicted the power of a high status subject as gained from a complex web created by those involved in defining the subject and constructing its syllabus (such as, for example, Syllabus Committees in the Western Australian system) and providing resources for its implementation and teaching (such as people in schools and school systems in Western Australia). Part of Goodson's web concerned also the post-school destinations to which school subjects are explicitly connected (e.g., through the specification of prerequisites for tertiary studies). In practice, subjects which lead explicitly to high status careers acquire high status themselves. Thus, "leading somewhere significant" becomes also part of the characteristics of a collection code subject.

In summary, the research of Goodson, Collins, Hargreaves and many others has illustrated that the categorisation of knowledge into clearly defined subjects is, in both a practical and an ideological sense, fundamental to its selective distribution in schools. Further, this previous research has demonstrated the enduring links between what Goodson (1983, p. 199) has termed "the deep structures of curriculum differentiation" and status hierarchies involving different social classes and occupational destinations. In this sense, two issues which are fundamental to this study become critical – the concept of access to

Collins' "positivist heartland" and the role of assessment in both determining this access and legitimating the positivist heartland.

THE CRITICAL ROLE OF ASSESSMENT

This chapter has described already the fundamental contribution of Young and Bernstein to theories about the ways in which education systems convert social hierarchies into academic hierarchies. As Young (1971a) suggested, questions should be asked about the context and definition of success and failure and how these are legitimated. More forcefully Apple (1978, p. 374) has asked "How is inequality made legitimate? Why is it accepted?" The previous section has argued that subject hierarchies in schools and school systems have an important role in legitimating this inequality. In this section it is argued that, without specific kinds of assessment procedures, the power of subject hierarchies in the legitimating process would be diluted considerably.

For the sake of clarity, this thesis uses the term "assessment" to cover the "collection of information about the nature and extent of students' learning" (Rowntree, 1977). Amongst other things, this will help to avoid confusion with the term "evaluation", which although selected by Bernstein (1971a) as the term to describe the third of his message systems, frequently is associated with determining the effectiveness of a curriculum, rather than, as is intended in this case, providing information about student learning.

The issue of assessment has been explored in a wide variety of educational research, much of it focused specifically on relatively technical aspects of testing and examinations. This thesis is concerned with research from a sociological perspective on a variety of forms of assessment. A considerable amount of this research has been generated

in the United Kingdom during the past decade and a half. The work of Broadfoot, on the interaction of "assessment, schools and society" (1979) is especially relevant (1980, 1982, 1984, 1985, 1986, 1990, 1993). In addition to this strong British flavour, however, the research of the American ethnomethodologist Cicourel (1974) in Southern California public schools was a valuable early contribution in the area, a contribution which, curiously, was not followed up in the US.

In a practical sense, it is clear that the power of the external examination as confirmatory evidence of the high status of a school subject has been recognised in many different contexts. As Goodson (1983) pointed out, the existence of an external examination is a central criterion for the granting of academic status to a subject, and those involved in such an exercise make reference, for example, to "survival via the exam racket" (p. 194). Thus, as he also noted (p. 34), it is no accident that the overwhelming influence of comprehensive schools was on academic examinations. Similarly, it is no accident that even successful examples of the abolition of external, subject-based examinations (as in Queensland in 1972 and the ACT in 1974) "have been unable to defeat the hegemonic myth that fairness requires a uniform curriculum and examination ritual" (Collins, 1989, p. 19).

From a more theoretical perspective, Bates (1980, p. 72) has drawn attention to the links between academic performance, cultural capital and the stratification/allocation of individuals within the social structure. In a similar vein, Goodson (1983, p. 199) reported finding that patterns of differentiation are associated with a "triple alliance between academic subjects, academic examinations and able pupils". Young himself pointed out (1977, p. 253) that systems are quick to legitimate the link between the academic and the examinable, or between the non-academic and the non-examinable. He noted also (p. 256) that the practices of examiners sustain

particular conceptions of school knowledge and pointed out that, in the case of school science, this conception presented an image of science as alien to pupils' everyday experiences, an image similar to that described earlier for *Physics* in Western Australia.

Some sociologists have focused also on the limiting effect of examinations on curriculum change. Although Eggleston (1975) has suggested that examination boards such as those in the United Kingdom are less important constraints on schools than teachers' own consciousness, Whitty (1977) has argued that such boards have "a significant effect on what counts as school knowledge" (p. 61) precisely because of their major influence on teachers' perceptions of what matters. In the terms of Sharp and Green (1975), Whitty argued that this kind of control over teachers (and thus over school knowledge) derives from the structural distribution of power and authority at the macro, system-wide level. In effect he saw examinations as a set of activities which help to legitimate and sustain definitions of school knowledge, and to constrain possible alternatives. Hextall (1977) went further, arguing that because examinations are part of the "'legitimation process' which serves to sustain a particular economic structure and political order (even) marking is not a technical activity but a political one" (p. 70).

Others have focused on the role of examinations in cementing the privilege of those who are already privileged. As early as 1971, Reimer argued that the then prevailing system of schooling in Britain, with its heavy emphasis on examinations, defined merit in such a way as to "allow members of the currently privileged class to retain their status in the new 'meritocracy'" (p. 29). Further, Bourdieu (1976) and Whitty (1977) argued that this is especially the case when the principles of what counts as successful performance are not fully explicated, as was the case in the mid-1970s in France and in the English General Certificate of

Education examinations. In such cases, those possessing cultural capital which assisted them to make sense of the implicit demands were advantaged and, as Whitty pointed out, such examinations served to legitimate privilege "by appearing to be objective and open to entrants from any class or culture on equal terms" (p. 71).

Whitty's (1977) comments in relation to the schools examination boards in the UK could apply equally well to the statutory authorities responsible for curriculum and assessment in Australia (such as the Secondary Education Authority in Western Australia). He emphasised that these bodies "contribute to the persistence of positivist conceptions of knowledge in society and to the elevation into absolutes of partial and culturally specific ways of engaging with the world" (p. 71). He argued strongly that, in the context of the UK, the examination boards were helping to legitimate the prevailing division of labour and the prevailing relationship between educational success and social class background. He commented further that the almost universal but essentially uncritical acceptance of the examination system's definitions of merit, standards and impartiality was itself "a powerful example of the capacity of an ideology to permeate the consciousness of much of society" (p. 71). In other words, it was a hegemony.

In relation to this hegemony, Broadfoot's sociological insights into assessment, as alluded to above, have been especially valuable. The breadth of Broadfoot's perspective is a particular advantage: it is broad in terms of its internationalism and in terms of its coverage of a variety of assessment strategies ranging from informal, pupil self-assessment to formal, externally set and marked examinations, and including also considerable research on the development of profiles of student achievement. Her fundamental observation was that "assessment practices reflect and reinforce the often conflicting values embodied in the

education system" (1979, p. 57). She illuminated this observation in the context of three trends in assessment at the end of compulsory schooling which she saw emerging in many different countries of the world. These concerned, first, the postponement of selection of students for tertiary studies; second, the shift away from formal, competitive, external examinations towards teacher assessment of a wider range of behaviours in a non-competitive context; and third, an increased interest in accountability issues and the use of assessment procedures to monitor accountability at both institutional and individual levels. In her discussion of these three trends, she focused on two themes:

the dynamic interaction between assessment procedures and changing social and economic forces and the series of checks and balances governing innovation in assessment procedures which ensures that the essential social functions performed by them – allocation and legitimation – are in no way threatened.

(Broadfoot, 1979, p. 58)

Broadfoot developed a dynamic model of the changing pattern of assessment, part of which is shown in Figure 2.4. Her model highlighted the direct relationship between the decline in external control on the continuum from formal to informal assessment, and the increase in external control at the system wide level. In other words, she showed that the price of an increase in school-based, informal assessment is an increase in system-wide monitoring tests!

From the point of view of this study, Broadfoot's model has three-fold significance. First, in highlighting the relationship between increasing informal assessment (at the school level) and increasing external examinations (at the system-wide level), Broadfoot demonstrated the role and importance of external testing as a legitimating agent. Second, although Broadfoot herself did not make the links, the model has

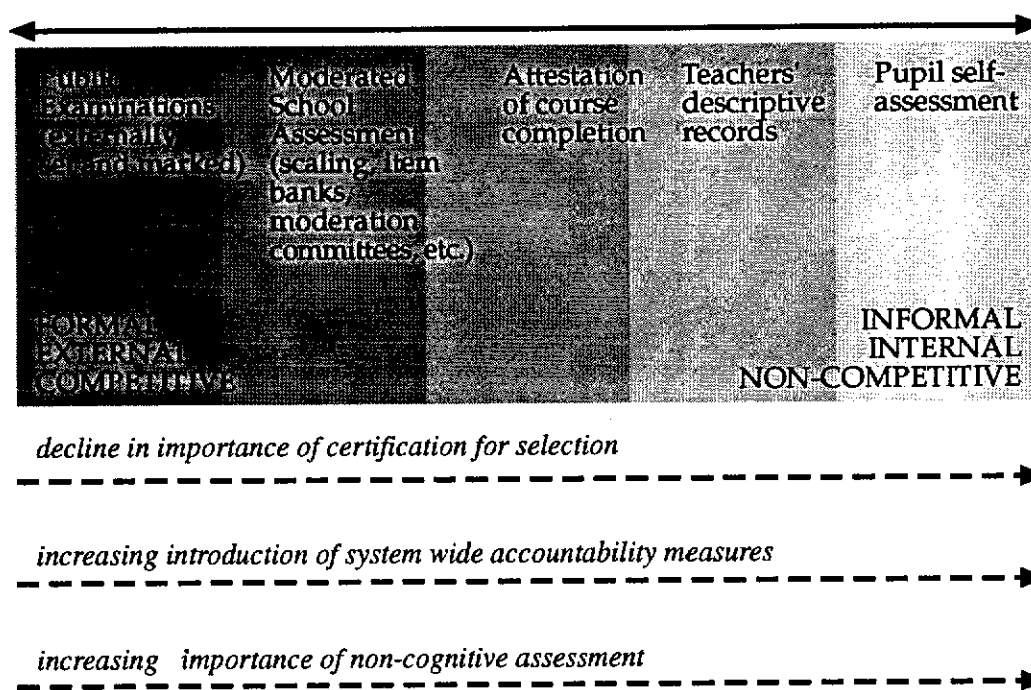


Figure 2.4. The continuum from formal (external, competitive) to informal (internal, non-competitive) modes of assessment. (After Broadfoot, 1979)

a strong relationship to Bernstein's codes. A shift from the left of Broadfoot's model to the right is, in Bernstein's terms, a shift from the collection to the integrated code, and can be added to the evolving theoretical framework of this study, as shown in Figure 2.5. Third, as is shown briefly in the next section of this chapter, and in more detail in Chapter 4, the model also has important links to the interaction of gender and assessment, an area which is seriously underdeveloped in much of the previous literature on assessment.

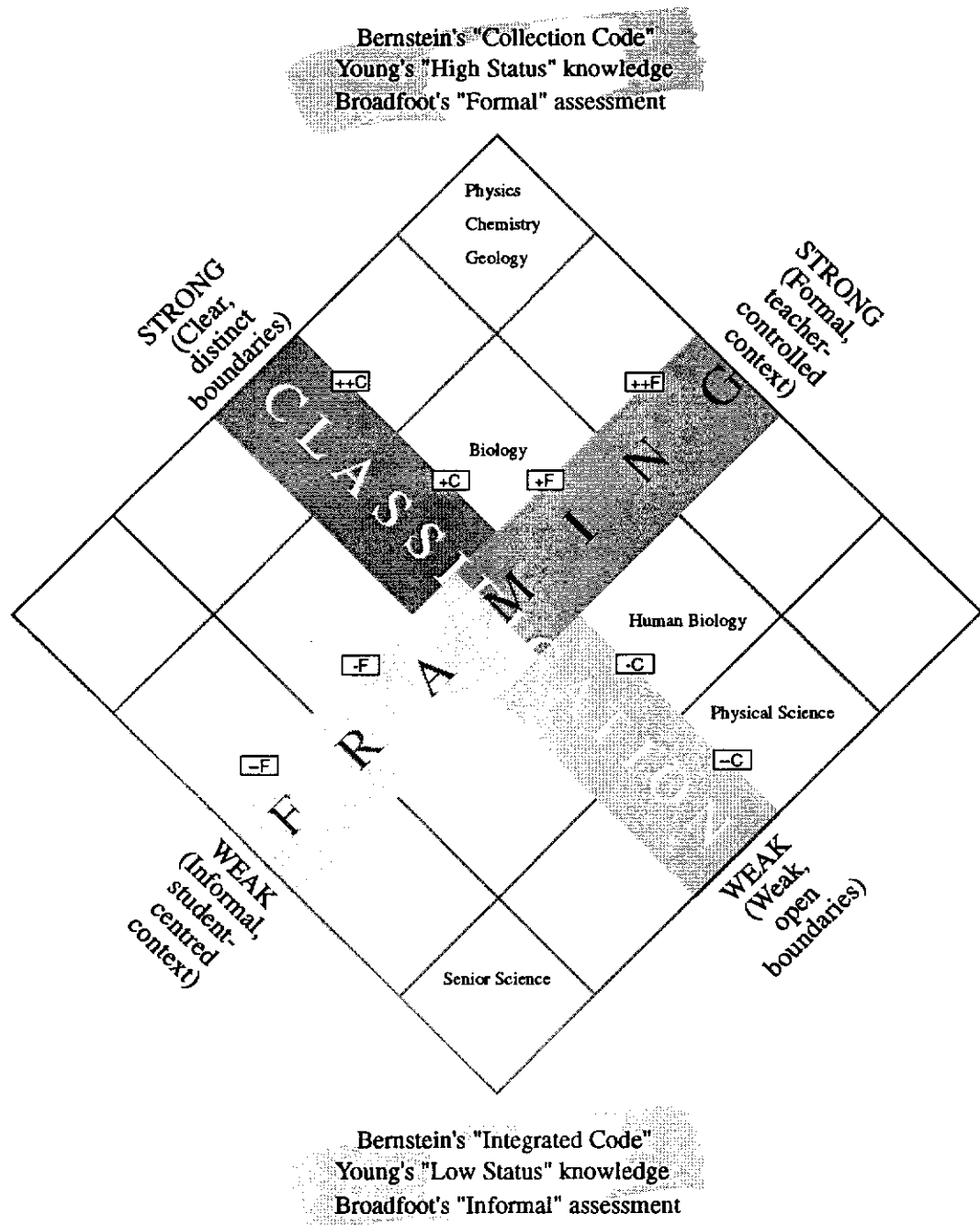


Figure 2.5. Reconceptualisation of the Bernstein/Young/Broadfoot models, showing positions of upper secondary school science subjects in Western Australia.

THE NEED FOR FURTHER REFINEMENTS OF THE BERNSTEIN/YOUNG/BROADFOOT MODELS

The research described in the two preceding sections of this chapter has gone a long way towards clarifying the earlier theorising of Young and Bernstein. As Smith (1988, p. 489) noted, there have been, amongst other developments, "refinements of (the) relativism" of the Bernstein/Young models and of their "largely incoherent critique of positivism". Clearly some contradictions and gaps remain, however. The questionable capacity of the original model of collection and integrated codes to describe adequately subjects of mixed classification and framing has been identified and rectified earlier in this chapter. Similarly, the lack of development of the "evaluation" message system in Bernstein's model of knowledge codes also has been identified earlier in this chapter, and the work of Broadfoot has been grafted on to the Bernstein/Young model in order to explicate this message system more satisfactorily.

Further gaps, with respect to social hierarchies, stem from the major preoccupation of both Young and Bernstein with class-bound hierarchies. Both saw social class divisions as the major outcome of the codification of knowledge in the school curriculum. As noted earlier, throughout their writing there was very little, if any, reference to sex-related divisions of educational knowledge, or to the relevance of their theories to gender-based hierarchies. Gender was mentioned occasionally by Young (as shown later in this thesis, in Chapter 6) and it was grafted in a rather unconvincing fashion on to Bernstein's later work [for example in his somewhat simplistic discussion of "modality of culture and gender" (1990, pp. 48-49)]. Indeed, despite Bernstein's acknowledgment of categories such as gender, ethnicity and religion, he maintained that it is

cultural reproduction through class which remains of paramount importance, and that the other categories "speak through class-regulated modes" (1990, p. 47). The position of this thesis is that the question of whether gender or class is paramount is a metaphysical question. As indicated in the definition of gender provided in Chapter 1, however, gender was viewed, in this study, as a fundamental category for organising social relations, and whether or not it "speaks through class" is not at issue here.

With few exceptions (e.g. Apple, 1979, 1982; Hextall, 1977, 1984), this lack of reference to gender is also characteristic of many of those who followed the "new directions for the sociology of education" steered by Young and Bernstein. With respect to assessment, despite the wealth of research on the controlling influence of examinations in the process of reproduction of class relations, there has been surprisingly little comment or research on any similar influence on the reproduction of gender relations. Hextall's (1984) research is outstanding in this regard, however. He was highly critical of the lack of sensitivity to race and, especially, gender issues in the examining process in the UK. In his view, the unspoken presumption that examinations speak a "universal language and convey a consensual culture" (p. 258) led to a situation in which race and gender were rendered invisible as structural categories. With a perceptiveness which was almost a decade ahead of its time, he found, in the work of the examining authorities,

no sense of a recognition that girls might have different relationships and feelings towards various areas of knowledge, towards different modes of learning, towards varying patterns of teacher-pupil relationship, towards the language in which problems are expressed...

(Hextall, 1984, p. 258)

Recent research on the relationship between gender and assessment, emanating principally from those involved with analyses of system-wide testing in the UK, has brought to light compelling evidence of gender differences in response to different kinds of assessment tasks. This research is reviewed in Chapter 4 of this thesis and, as is demonstrated in Chapters 7–9, it provided an important point of reference for the discussion of the data gathered and analysed in the present study.

SUMMARY OF THE THEORETICAL POSITION TO THIS POINT

This chapter began with a detailed critique of the fundamental contributions of Basil Bernstein and Michael Young to the sociology of school knowledge. It reconceptualised their theories about the stratification and codification of school knowledge, identifying and addressing some of remaining deficiencies. It plotted the evolving model diagrammatically, culminating in Figure 2.5, which shows the additions of an expanded notation for classification (C) and framing (F), and of the Broadfoot (1979) formal–informal continuum of assessment procedures. It also identified as problematic the preoccupation of the Bernstein/Young models with social class, and the virtual absence of gender from the models. In this sense, the questions explored in the next part of the study, and reported in Chapters 4 and 5 of this thesis, concern, first, the extent to which gender can be incorporated as a central feature of the theoretical framework which has begun to be developed in this chapter and, second, the extent to which this framework provides a basis for conceptualising the relationship between gender and science education.

Chapter 3

METHODOLOGY: THEORY BUILDING AND THEORY TESTING

INTRODUCTION

Purpose of the Chapter

As indicated in Chapter 1, the purpose of the study reported here was to advance understanding of the relationship between gender and science through the development and testing of a theory. This chapter provides a detailed description of the methodology used to achieve this purpose. The chapter begins with some general comments, emphasising the eclecticism of the methodology and its focus on both critique and action. More specifically, a definition of the term "theory", as used in this thesis, then is provided. Next, three important aspects of the methodological background of the study are discussed, namely, the focus on curriculum and assessment, the feminist perspective and the personal perspective. In the final section, the two phases of the study are described – first, the theory-building phase, in which existing strands of theory were integrated into a new theory proposing that school science is gender-coded and second, the theory-testing phase, involving a socio-historical analysis of upper secondary school science in Western Australia over the period 1976–1993.

The General Approach

The first phase of the two phases of this study concerned the building of theory about the transmission of scientific knowledge through formal education. The second phase involved the testing and revisiting of the theory which had been built, with particular reference to implications for educational policy and practice impinging on the relationship between gender and science. The focus was on both critique and action, because, as Young has pointed out

a theoretical critique of the necessity of hierarchies of knowledge and ability may be exciting in a seminar, but is not any good to those who experience such necessities as real in practice. The problem, then, is not to deny or accept these hierarchies as necessary, but to try to reformulate them as not the order of things, but as the outcomes of the collective actions of men (sic) – and thus, understandable and potentially changeable.

(Young, 1977, p. 247)

The approach taken was eclectic, drawing, like the work of Bernstein and Young which provide the springboard for the whole study, on the explanatory power of a variety of approaches. As emphasised by Karabel and Halsey (1977) this eclecticism provides considerable strength for research undertaken within the sociology of knowledge paradigm. Specifically, they noted that work such as that of Bernstein, because it drew on both normative and interpretive methods, was able successfully to integrate structural and interactional analysis. The result of such research, as Karabel and Halsey saw it, was

a series of bold explorations into the content of the educational process that, in their effort to relate what goes on in school to larger structures of power and control, point the way toward a potential new synthesis in the sociology of education.

(Karabel & Halsey, 1977, p. 68).

The study reported here continued in the tradition of these bold explorations. However, unlike most of the previous explorations of the Bernstein/Young theories, which were predominantly phenomenological studies of schools and classrooms, the focus in this study was more at the structural, systemic level, and on ways in which different curriculum and assessment policies appear to influence the relationship between gender and science. This is a particularly significant contribution, because, as Hargreaves (1989, p. 68) has emphasised, "the structural level is precisely the one at which much of the future of schooling is now being shaped".

The Definition of "Theory"

The literature in the behavioural and natural sciences is marked by a certain amount of confusion regarding the use of the term "theory". As noted by several philosophers and researchers, there is no one definitive meaning for the term, and in many cases it is used interchangeably with terms such as "model", "conceptual framework", "theoretical framework" and "hypothesis". In summarising a number of interpretations of the term, O'Connor (1957) commented that "there seems to be fairly general agreement among scientists and philosophers who write about scientific method that theories fulfil three functions: (1) description, (2) prediction, and (3) explanation" (p. 81). Not all researchers are quite as definite about a theory needing to have all three functions, however. Wiersma (1986, p. 19), for example, as indicated in Chapter 1 of this thesis, defined a theory as providing "a framework for conducting research, and it *can* be used for synthesising and explaining ... research results" (*italics added*). More specifically, Hawking (1988, p. 10) stated that a "good" theory satisfies two requirements: "it must accurately

describe a large class of observations on the basis of a model that contains only a few arbitrary elements, and it must make definitive predictions about the results of future observations". Further, even O'Connor (1957, p. 76) indicated that the term can be used to refer to "a hypothesis that has been verified by observation".

In this study, as is explained in Chapters 4 and 5, the theorising was based on the hypothesis that school science is gender coded in ways which associates maleness with Bernstein's collection code, Young's high status knowledge and Broadfoot's formal assessment procedures, and femaleness with Bernstein's integrated code, Young's low status knowledge and Broadfoot's informal assessment procedures. The study demonstrated that this hypothesis is supported by the research of feminist scholars (Chapter 5) and by empirical evidence from studies of students' participation and achievement in school science (Chapter 4). It also verified the hypothesis with reference to new empirical evidence regarding students' participation and achievement in school science under different curriculum and assessment structures (Chapters 6, 7 and 8). The criteria of description and prediction both are satisfied clearly by the outcome of this thesis. In addition, the outcome has some explanatory power, although, as indicated in Chapter 9, a rather different kind of study would be needed to demonstrate this explanatory power completely. Overall, however, the outcome of this study is consistent with the interpretations of the term theory provided by Wiersma, Hawking, O'Connor and indeed many other researchers.

BACKGROUND

The Focus on Curriculum and Assessment Policy

Until relatively recently, the science education research literature has made only passing reference to the influence of the structure of system-wide curriculum and assessment policy on science education. The reasons for this are a matter of conjecture. Perhaps researchers view their capacity to influence policy and design at the total system level as somewhat limited, and tend therefore to focus their work at the level of the school, subject or syllabus, which they perceive to be more amenable to change. Or perhaps the influence of system-wide curriculum/assessment design is so pervasive and obvious that it is regarded tacitly as a taken-for-granted background factor – hardly even a "variable" in the typically accepted sense.

In the current context, with the increasing tendency towards nationally-based approaches to curriculum in a number of countries of the world, there is a clear need to focus more sharply on curriculum/assessment design at the whole-of-system level. In Australia the influence of this variable always has been particularly significant, given the highly centralised nature of the curriculum/assessment structure in each Australian state. Indeed, as was demonstrated in this study, a wealth of information about the limits and possibilities of different system-level designs lies somewhat dormant in the annals of Australian education research.

In a general sense, the advantages and disadvantages of various approaches to the design of curriculum and assessment have been debated for many years. In relation to curriculum, for example, Saylor and Alexander (1974) presented an excellent summary of the debate, comparing and contrasting designs focused on specific competencies, on social activities and problems, on process skills, on individual needs and interests, and on disciplines/subjects. They also provided a set of guidelines for selecting appropriate curriculum designs, emphasising the

need for a systematic approach, with a sound theoretical and empirical basis. Similarly, in relation to assessment there has been much debate, and there are many well established references describing and analysing various assessment modes (e.g. Mehrens & Lehmann, 1969).

There is no denying the value of such analyses. There are, however, a number of problems associated with their translation into practice. Paramount amongst these problems is that, in reality, curriculum/assessment policy-making and designing does not begin with a blank slate. It occurs in an intensely political environment embracing legacies from history, and it must take account of the different, possibly conflicting, ideologies and aims of many stakeholders. Moreover, even designers and policy-makers seeking research and evaluative data upon which to base their decisions find such data to be limited to curriculum/assessment design for specific areas or subjects in the curriculum (e.g. Goodson, 1985). Only recently, with the considerable research effort directed, in England and Wales, to critiques of the new General Certificate of Secondary Education (GCSE) (introduced in 1988) and the even newer National Curriculum structure (introduced in 1991), has system-wide change to the total structure of curriculum and assessment come under systematic scrutiny. Thus inevitably, the availability of reliable evaluative information in this regard has been quite limited. More specifically, until very recently, with the emergence of some analyses of the implementation of the Victorian Certificate of Education (VCE) in the State of Victoria in Australia (Hildebrand & Allard, 1993) and of the National Curriculum in England and Wales (Murphy, 1993) evaluative information which takes account of gender has been almost non-existent.

Like Victoria and the UK, however, Western Australia has experienced several major changes to the structure of secondary

education in recent years. This study drew together research data relating to the apparent effect on science education of some of those changes, focusing in particular on the relationship between gender and science. As argued elsewhere (Andrich & Parker, 1980), the study of situations characterised by the introduction of a new element into a relatively stable environment can be highly productive, because the new element may so destabilise the status quo that interrelationships among variables become magnified and more readily examinable. From a sociology of knowledge perspective, a destabilised, changing social context provides a rich research milieu, one in which "ideas which transcend the framework of existing social relations can grow" (Danziger, 1973, p. 362). In this sense, then, the Western Australian data analysed in this study provided a particularly effective basis for the testing of a theory about the relationship between gender and science, a theory built on the foundation provided by Bernstein and Young, as presented in Chapter 2.

The Feminist Perspective

The feminist perspective of this research has been emphasised already in Chapter 1. Whether or not this perspective has any specific methodological implications and whether or not there is a distinctive feminist method of scientific inquiry has been debated by number of feminist scholars. Some (e.g. Lather, 1988) argue that feminist research carries with it a commitment to transformative action, a commitment similar to that made at the outset of this chapter, following Young (1977). Sandra Harding, in her extensive research and writing on the question, argued against the idea of a single "feminist method". She considered that "preoccupation with method mystifies what have been the most interesting aspects of feminist research processes" (1989, p. 17). However, she did suggest three characteristics which she saw as "distinguishing the

most illuminating examples of feminist research" (1989, p. 26) and, while acknowledging the implications of each of these characteristics for the selection of research methods, she was unwilling to call them methods in their own right. The three characteristics are, first, the discovery of gender and its consequences, second, the inclusion of women's experiences as a scientific resource, and, third, an insistence on gender-sensitive reflexive practice by the researcher.

In relation to the discovery of gender, Harding pointed out that, while there has been much research throughout history on women's nature and habits, the idea that masculinity and femininity are constructed socially rather than biologically is very recent. Further, she emphasised that feminist research examines gender critically, asking how gender accounts for women's oppression, and how gendered beliefs "provide lenses through which researchers in biology and social science have seen the world" (1989, p. 27). She argued also that one consequence of this discovery of gender has been the development of the second of the features she identified in "illuminating" feminist research, namely, a focus on women's experiences as both a source of questions and an indicator of reality against which hypotheses are tested. By implication, she suggested that the questions posed by feminist researchers tend to arise from desires to cooperate, nurture and live in harmony with nature, and to understand women as human beings in their own right, rather than as a lesser or deviant form of men.

Harding's third characteristic of a feminist approach to research concerned the explicit acknowledgment by researchers, as part of their research, of their own beliefs and background. Thus, in her vision, "the researcher appears...not as an invisible, anonymous, disembodied voice of authority, but as a real, historical individual with concrete, specific desires and interests" (1989, p. 29). Her view was that "a maximally

objective science, natural or social, will be one that includes a self-conscious and critical examination of the relationship between the social experience of its creators and the kinds of cognitive structure favored in its inquiry" (1986, p. 250).

The methodology of this study was explicitly feminist in terms of the first and third of Harding's three criteria. In relation to the first criterion, while the study did not purport to "discover" gender, it certainly demonstrated the centrality of gender to theories regarding the definition and distribution of worthwhile knowledge. In relation to the third criterion, as will be explained in the following section, the research arose from and was conducted in the context of an intensely personal involvement with the interaction between gender, science and the sociology of knowledge. Because this involvement has been so personal, it is appropriate to describe it in a narrative style, using the first person pronoun.

The Personal Perspective

My personal involvement with science and science education goes back many years. As a schoolgirl (attending a school, the motto of which translated as "Knowledge is Power"), I studied science at the highest possible level. This was due partly to enjoyment and commitment and partly to the special regard which other students had for their peers who studied science and mathematics – in other words, the high status attached to the "positivist hegemony". In my first degree, I majored in chemistry and, immediately upon graduating, was appointed as a research officer in a team working in microbiology. Subsequently I obtained several similar positions in a variety of universities throughout the world. During this period, although I enjoyed the work and in no way considered the possibility of challenging the dominant scientific

paradigm within which I worked, I missed increasingly the human dimension in my work. Thus when, after a short career break, the opportunity arose to teach science and mathematics at school level, I seized upon it.

In association with my teaching I undertook further studies in education, culminating in a postgraduate research project, in which I pursued my newly found interest in the sociology of education. In that project, I focused on parental attitudes to coeducation especially in relation to girls' science and mathematics education. I began the research with a belief that girls needed, as I myself had had, the best possible traditional science and mathematics education and, further, that a coeducational school was the best environment for obtaining this education. By the end of the project, not only had these beliefs suffered a considerable dent, I was also considerably less comfortable with science and mathematics education as traditionally undertaken.

*During my subsequent positions as a teacher educator and as a senior officer in a statutory authority responsible for Statewide secondary school curriculum and assessment, I continued whenever possible to research gender issues in science and mathematics education. I became a contributor to the feminist critique of girls' education in Australia and an active participant in the work of the international GASAT association. As a member of the Commonwealth Schools Commission Working Party on the Education of Girls, I carried the major responsibility for the production of the report *Girls and Tomorrow*, which recommended major changes in girls' education in Australia.*

My interest in undertaking a study such as that reported in this thesis developed from this background. My professional practice has been interwoven increasingly with my research interests. My readings and discussions with others have both illuminated my work and, in the

manner discussed by Lather (1988), empowered me through developing my understanding of the forces acting to shape my life. It is in this context that the theory building and theory testing carried out in this study have taken place.

THE THEORY-BUILDING PHASE OF THE STUDY

Hawking (1988), in his description of theory-building in the physical sciences, noted that "in practice what often happens is that a new theory is devised that is really an extension of a previous theory" (p. 11). Similarly, Van Dalen (1979), in relation to the social sciences, noted that "science develops by building cumulatively on the existing body of facts and theories". He went on to comment that "a useful educational hypothesis, therefore, adds something to previously established knowledge by supporting, qualifying, refuting, or enlarging upon existing theories" (p. 79). Similarly, the position of Selltitz, Jahoda, Deutsch and Cook (1965) was that part of the exercise of theory-building consists of the clarification, reformulation and refocusing of existing theories. They explained that this involves identifying gaps in existing theories and identifying relationships amongst existing theories, culminating in a new conceptual framework which provides a basis for further research and which informs policy and practice. Such was the case in this study. Essentially, as indicated already in previous chapters, the approach taken was reminiscent of that taken by Berger and Luckman (1967) in the development of their theory about the social construction of reality. While the enterprise was both less ambitious and of a smaller scale than that of Berger and Luckmann, the basic technique of weaving together some existing strands of theory and empirical research, while at the same time recognising and filling holes in the resultant fabric, was similar.

This approach to theory-building attracts some support from the general community of educational researchers. Ginsberg and Meyenn (1979), for example, suggested that attempts to synthesise the major perspectives in the sociology of education and other disciplines "are extremely important and valuable in providing the necessary underpinning for conceptualizing and interpreting educational research" and are likely to lead to "a new and propitious era of educational research" (p. 96).

Some of the existing theoretical strands woven together in this study have been discussed already in Chapter 2, namely, the theories of Bernstein and Young concerning the relationship between social class and the definition and distribution of school knowledge. In the first stage of elaborating the Young/Bernstein theories, the focus, as described in the latter part of Chapter 2, was on legitimation. It was shown that Broadfoot's analysis of patterns of contemporary assessment could be mapped onto the concepts of classification, framing, collection code and integrated code, and that this mapping made more explicit the role of assessment in legitimating the definition and distribution of high and low status school knowledge.

The second and third stages of the theory building and elaboration focused on science and on gender, and on the significance of the interaction between gender and science in relation to the work of Young, Bernstein and Broadfoot. Reflecting the commitment to action identified by Young (1977), the second strand woven into the fabric of this study, as shown in Chapter 4, came from empirical evidence regarding the ways in which the structure of school science curriculum and assessment appear to influence the relationship between gender and science. From this empirical perspective a picture of a more gender-inclusive science was sketched. As shown in Chapter 5, this picture was confirmed from a

theoretical perspective in the third stage of the theory building, through an analysis of the writings of feminist scholars. In addition, the picture was mapped onto the framework developed in Chapter 2, and through this process the concept of school science as "gender coded" was developed.

The elaborated theoretical framework produced in this study, like the theories of Bernstein and Young from which it was derived, is an example of the many two-dimensional social classifications found in the sociological literature. As discussed in detail by Ostrander (1982), these classifications share "an underlying concern to account for the distribution of beliefs according to variation in social experience" (p. 15). Further, like the grid-group classification of Mary Douglas (1982), the gender code theory developed in this study was "intended to have the sort of general applicability necessary for analysing the relationship of the social and symbolic orders" (p. 15). Whether it had this applicability was tested in the next phase of the study, through a socio-historical analysis of enrolment and achievement in school science in Western Australia over the 25 year period between 1969 and 1993.

THE THEORY-TESTING PHASE OF THE STUDY

The Socio-historical Approach

The theory-testing carried out in this study was in the tradition of socio-historical analyses as undertaken previously, for example, by Layton (1973), Goodson (1983, 1985) and Reid (1985). There is a strong rationale for undertaking studies which combine a sociological analysis with an historical approach, rather than conducting the two in isolation from one another. Goodson (1985), for example, has identified a tendency for the sociology of knowledge, on its own, to be ahistorical. He

maintained that, with few exceptions, "sociological studies of the school curriculum have maintained an obsessive contemporaneity at the expense of any serious consideration of historical context" (p. 1). Conversely, however, he pointed out also that "historians of education have often inverted the problem and largely failed to link insights into curriculum past with perspectives on curriculum present" (p. 1). He pointed to a need to combine the two, in order to produce a view in which past and present are balanced, a view which optimises the possibilities for understanding curriculum issues and curriculum change. He cautioned, however, against something which Silver (1977) has called the "raiding" of history – the capturing of "snapshots from the past to prove a contemporary point" emphasising that it is important to plot the recurrence of events and that the patterns resulting from such plotting help in "discerning explanatory frameworks in which structure and interaction interrelate" (Goodson, 1985, p. 344).

Goodson (1985) noted also that, in their later writings, Young and Bernstein themselves argued for historical work. Young (1977) for example noted that "one crucial way of reformulating and transcending the limits within which we work, is to see...how such limits are not given or fixed, but produced through the conflicting actions and interests of man (sic) in history" (pp. 248-249). Similarly, Bernstein (1974) argued that "if we are to take shifts in the content of education seriously, then we require histories of these contents, and their relationships to institutions and symbolic arrangements external to the school" (p. 156).

In the case of the study reported here, a socio-historical analysis was seen to have four specific advantages. First, it was able to offer insights into the existence of patterns of participation and achievement in science, not only sex-related patterns, but also patterns related to socio-economic status, an important variable in terms of the original

Bernstein/Young theories. Second, by linking these patterns with specific changes in the structure of curriculum and assessment, it was able to identify some apparently recurring constraints upon the study of science by females and to draw attention to the beliefs and ideologies which appear to influence students' subject choices and achievement. To some extent, model-building depends on establishing patterns. Cross-cultural studies do this by comparing different cultures at the same time, whereas socio-historical studies do it by looking at the same culture over an extended period of time. Third, the socio-historical analysis highlighted patterns of the survival of subjects within the science curriculum, pointing again to the ideological underpinnings of the curriculum. Fourth, this kind of analysis, focusing as it does on curriculum and assessment in a relatively centralised education system, is able to inform educational policy and practice. As Goodson (1985, p. 7) noted in relation to centralised education systems, "only what is prepared on the drawing board goes into the school and therefore *has a chance* to be interpreted and to survive". Thus, while not denying the important roles of teachers and students in curriculum implementation, understanding the patterns associated historically with the implementation of specific kinds of curriculum and assessment policies is critical to practitioners at all levels of education.

The Data Base and Sources

The socio-historical analysis in this study involved three major tasks. First, a data base was established, spanning the years 1976–1993, documenting Western Australian students' participation and achievement in upper secondary school science subjects. Data pertaining to the seven upper secondary science subjects (*Biology, Chemistry, Geology, Human Biology, Physical Science, Physics and Senior Science*)

over the period 1976–1993 were obtained from the records of the Secondary Education Authority. The enrolment data were differentiated according to

- proportion of male and female students in each subject
- proportion of students in each quartile of "general ability" in each subject [estimated from the students' mean scores on the Australian Scholastic Aptitude Test (ASAT)]
- proportion of students from Government and non-Government schools in each subject [thus providing, as indicated by the Ministry of Education "Index of Disadvantage" for Western Australian schools (Western Australia. Ministry of Education, 1992) an approximate measure of the socio-economic balance of students in each subject].

For the purposes of this study, data on *Geology* and *Senior Science* were not used, because enrolments in these two subjects were extremely low. In the other five subjects, students' scores in the Statewide TAE or TEE were used as the measure of achievement. These scores were of two types. First, for each of the years 1976–1993, students' raw examination scores, based entirely on the external examination, were available. Second, because of changes which occurred in 1985 (which will be explained in greater detail in Chapter 7 of this thesis) for each of the years 1986–1993, a "Scaled Combined Score" which included approximately equal weightings of scores from the external examination and from school-based assessment also were available in each subject. For the purposes of this study, the means and standard deviations of males' and females' raw TAE/TEE scores (1976–1993) and of their Scaled Combined Scores (1986–1993), for all major TAE/TEE science subjects, were calculated. For each subject, in each year, the difference between the performances of males and females was represented as an effect size.

Following the statistical technique established by Cohen (1969) and used extensively by many researchers in this area (e.g. Giaconia & Hedges, 1985; Glass, 1977; Keeves, 1992), the effect size was calculated by dividing the difference between mean scores for males and females by the common, within-group standard deviation. The usual conventions were adhered to in interpreting these effect sizes, namely,

- in relation to direction, positive effect sizes were interpreted as indicating higher achievement by males and negative effect sizes as indicating higher achievement by females, and
- in relation to magnitude, an effect size of less than 0.2 was considered trivial and progressively larger effect sizes were deemed small (between 0.2 and 0.5), moderate (between 0.5 and 0.8) and large (in excess of 0.8).

It should be noted that, in tangible terms, Cohen (1969, p. 20) has shown that an effect size of 0.3 means that the upper 50 percent of students in one group exceeds the performance of 62 percent of the students in the other group and further, that this interpretation is independent of the sizes or complexities of the samples. In even more tangible terms, Keeves (IEA, 1988) has shown that an effect size of 0.3 is approximately equivalent to what is typically learned during a year studying science at the lower secondary school level.

The second major task undertaken for this study involved research and documentation of policies affecting the structure of science curriculum and assessment which operated in Western Australia during the period 1969–1992. Particular attention is paid to changes which took place, at both upper and lower secondary levels, during the period in question. This task involved the scrutiny of documents from a variety of sources, including, as well as documents and reports in the public domain, the minutes of committees retained

in the archives of the Secondary Education Authority [minutes of the Secondary Education Authority, of the two major Authority committees (the Curriculum and Assessment Policy Committee and the Tertiary Entrance Score Subject Committee) over the period 1985–1990, and of Syllabus Committees for all science subjects over the period 1978–1990] and other documents associated with the development and evaluation of the new upper secondary school subject, *Physical Science*, in 1978 (Boud, Dynan, Parker & Ryan, 1979; Dynan, Parker & Ryan, Physical Science Evaluation Project, Document RE/DPR/012, 1978; Dynan, Parker & Ryan, 1979; Education Department of Western Australia, 1975, 1978).

In the third major task, the data base established as a result of accomplishing the first two tasks was analysed, with the aim of identifying any links between curriculum/assessment policy and patterns of science participation/achievement. The analysis focused on the two specific questions of whether changes in curriculum/assessment policy appeared to be associated with changes in science participation/ achievement of students, and whether the pattern of association between curriculum/assessment policy and science participation/ achievement varied systematically with students' sex, ability and socio-economic status. This analysis was carried out at the level of the individual science-for-all subject *Physical Science* (reported in Chapter 6) and at the level of the total secondary science curriculum (reported in Chapters 7 and 8).

Theory Revisited

The analysis described above was interpreted in terms of the emerging theoretical framework built in the earlier part of the study. This stage of the study involved the integration of the study's

theoretical phase (which wove together major strands from the sociology of knowledge, previous research on gender and science, and feminist theories about gender and science) with the empirical, socio-historical analysis. The theory generated from this synthesis appeared to have both descriptive and predictive power regarding the relationship between gender and the structure of school science curriculum and assessment. It thus constitutes a significant elaboration and integration of the previous work of Bernstein, Young and Broadfoot, and of feminist scholars such as Keller, together with empirical evidence from schools and school systems.

SUMMARY

This chapter has provided details of the methodology of the study. The theory-building and theory-testing phases have been described, emphasising the eclectic approach, the focus on secondary school science curriculum and assessment, and the personal, feminist perspective. The chapter provides a strong rationale for the use of a socio-historical analysis in theory-testing, demonstrating, as noted earlier by Goodson (1985), that "pursuing an understanding of the complexity of curriculum action and negotiation over time is a meaningful sequence through which to test, and formulate, theory" (p. 345). The next chapter takes up the theme of critique and action emanating from Young's (1977) view that hierarchies of knowledge are the outcomes of collective actions by human beings. It focuses on ways in which actions in schools and school systems have been able to challenge, successfully, the gender-based hierarchies in school science.

Chapter 4

SCHOOLS, SCHOOL SYSTEMS, SCIENCE AND GENDER

INTRODUCTION

Purpose of the Chapter

Chapter 2 of this thesis presented the initial theoretical framework of this study. It indicated that, to date, the application of this kind of framework has focused almost exclusively on class-based hierarchies of knowledge and further, that the focus has been in a theoretical sense rather than an empirical sense. The purpose of this chapter is to explore the extent to which the framework has application to gender-based hierarchies of knowledge, specifically in relation to scientific knowledge as represented in secondary school science curricula. Essentially, this chapter is concerned with the manner in which school science curriculum and assessment policy and practice appear to interact with gender. The primary focus is on previous research demonstrating the kinds of contribution to the gender/science relationship made by certain features of schools, school systems and science through which curriculum and assessment policy are operationalised. The chapter builds, from a practitioner's perspective, a picture of what a more gender-inclusive school science might look like. In building this picture, it draws both from a general background of research on educational disadvantage, and from research which focuses more specifically on

science education (and to some extent, as explained in the following section, research in mathematics education).

The Links with Mathematics

Much of the research and policy activity pertaining to gender and science has been linked closely to that in the area of gender and mathematics. However, as noted by Kahle, Parker, Rennie and Riley (1993), in the area of theory-building (particularly the building of theories about cognitive abilities from a psychological perspective), the work on gender and mathematics has moved ahead of that on gender and science. Theoretical models developed by mathematics educators, in particular the Academic Choice Model (Eccles, Adler, Futterman, Goff, Kaczala, Meece & Midgley, 1983) and the Autonomous Learning Behavior model (Fennema & Peterson, 1985) have been useful in some research about gender and science (Kahle & Meece, 1992; Meyer & Koehler, 1990; Reyes, 1984). Further, important recent research on gender and mathematics has some clear links to research on gender and science (e.g. Burton, 1992; Fennema & Leder, 1990; Leder, 1992; Willis, 1989). There are limits, however, to the extent to which this work on gender and mathematics is directly and specifically applicable to research and practice in the area of gender and science. Kahle et al (1993) argue that the explicitly multidisciplinary nature of science compared to the more unidisciplinary nature of mathematics, the perceived lower educational value of science compared to mathematics and, above all, the much more strongly masculine image of science (particularly physics) in comparison to mathematics, dictate the need for a fresh perspective on theorising in the area of gender and science. Thus, while a substantial amount of the literature reviewed in this chapter pertains to both mathematics and science, the uniqueness of science should be kept in mind.

Overview of the Chapter

The chapter begins with an overview of the major categories of explanation for gender differences in science, arguing, from a pragmatic, reformist perspective, the case for explanations focusing on variables which can be altered. It then presents a summary of research demonstrating that science-related gender differences vary over time and between cultures, and notes two significant directions arising from such research: first, the proposal of some theoretical frameworks based on a sociocultural approach; and, second, a body of research on factors in schools and school systems which appear to make a difference to the relationship between gender and science, specifically in terms of humanising the masculine image of science. This latter body of research is explored in considerable depth, focusing initially on the factors common to strategies which appear to have been successful in changing the relationship between gender and science, then on specific features of schools and school systems. In the latter context, the specific focus is on features concerning the portrayal, organisation and assessment of scientific knowledge by schools and school systems. Taking the view that these features are socially constructed, the chapter identifies ways in which they can be reconstructed to produce curriculum and assessment arrangements which are more gender-inclusive. It concludes with a summary of these features, linking them to the initial theoretical framework developed in Chapter 2.

BACKGROUND

Classes of Explanation: Implications for Practice

In the literature addressing issues of gender and education, a number of conceptually and ideologically different classes of explanations

for gender differences in science have been advanced, each of which has its own unique implications for research and practice. The predominant focus of the relatively few early researchers and practitioners in the area of gender and science was on explanations with a genetic or cultural basis. These explanations essentially were deficit models, described by many sociologists as "blaming the victim". Such models implied that the structure of schools and the structure of society were satisfactory, and that, if females were not participating and achieving well in science, then there was something at fault in the females themselves. In the one case the fault was seen to lie in the females' genes, and in the other case in their cultural background and in the way in which they interpreted messages from this background. With respect to implications for practice, clearly neither genes nor culture is readily alterable. Intervention strategies based on deficit models focus, therefore, on helping females to accommodate to the status quo. Those maintaining a genetic deficit approach tend to follow the prescription of Gray (1981, p. 52): "What, then, should be done about sex differences in science achievement...? The answer is, nothing." Those maintaining a cultural deficit stance tend to follow a compensatory path, typified by the many projects in the 1970s which focused on changing females' attitudes or skills to make them more likely to succeed in school science – in a sense changing females to make them more like males.

The deficit models contrast with other classes of explanation emerging in later research and practice, which focus on "blaming the system". Evidence for system-based explanations comes from research exposing the structural barriers to women's participation in science, barriers of institutional origin [such as those obstructing women's acceptance into the academies of science (see, for example, Bernard (1964)); of occupational origin [such as those limiting women's

employment in science and technology, as documented by Haas and Perrucci (1984), Malcom (1976) and Vetter (1983)]; and of educational origin [such as those documented by Hornig (1984) and others referred to later in this chapter]. These explanations tend to avoid any implication of deficits in females. They fall into two major groups: those which focus on factors in schools or school systems and those which focus on socio-political dimensions. The socio-political variety see a flawed, inequitably structured society as the root of the problematic relationship between gender and science, and propose strategies aimed at altering the structures of patriarchal, capitalist societies. Again, however, as in the case of strategies premised on genetic or cultural explanations, such strategies clearly involve a set of variables not readily amenable to alteration, especially by educators operating within a State-run system.

As indicated earlier, the major focus of this study was on the category of explanations involving school-based or school system-based variables, including the representation of science knowledge as one of these variables. The reason for this focus related to the study's overall commitment to action: clearly, these variables are amenable to alteration by policy and practice at the school or system level. Thus, in its review of research relevant to these variables, this chapter makes two major points. First, gender differences in science are not fixed; they vary with different cultures and contexts and they vary over time within the same culture. Second, although some of the conditions which are associated with variations in gender differences in science are outside the direct control of schools or school systems, many are not. Given appropriate conditions, factors over which schools and school systems have control do make a difference to the way in which the relationship between gender and science develops and endures.

Variations between Cultures and Variations over Time: The Development of Some Explanatory Frameworks

Variations in science-related sex differences can be demonstrated from studies of international comparisons which have been conducted in recent years. Two of the major bodies of quantitative data relevant to such comparisons are those emanating from the first and second studies of science education conducted by the International Association for the Evaluation of Educational Achievement (IEA) in 1970 and 1983. The first was reported initially by Comber and Keeves (1973) with a later analysis of sex differences presented by Kelly (1978). The second was reported by Keeves (1992) and included specifically an analysis of sex differences carried out by Keeves and Kotte (1992). In both studies the general direction of the sex differences in achievement was the same across all 19 countries sampled. Overall it was in boys' favour, greatest in physics, somewhat smaller in chemistry and smallest (at times non-existent) in biology. The magnitude of the sex differences was smaller in the second study than in the first, thus demonstrating a change over time. Further, the magnitude varied considerably from one country to another, and in some cases the level of achievement of girls in one country was higher than the level of achievement of boys in another.

The finding of variation in the size of the sex differences in science achievement across cultures suggested that, although there might be factors which operated consistently in all cultures to enhance the science achievement of males or depress that of females, there also might be other factors, such as those associated with the culture or the education system, which contributed to the cross-cultural differences. This suggestion led initially to the proposal by Kelly (1978) of a cumulative model for explaining the development of sex differences in achievement and attitude in school science. Her model depicted girls' and boys' innate

intellectual and social potentialities initially as two intersecting sets with a very large area of intersection. Following the influence first of cultural variables and pressures and then of school-based variables, the model, in the final analysis, portrayed a much smaller area of intersection between the sets representing boys' and girls' achievement in and attitudes towards science. Kelly's model was useful to the extent that it distinguished genetic, cultural and school-based variables as three broad classes of influences bearing on science-related sex differences.

Generally, findings from the first IEA study led to a considerable amount of research which endeavoured to establish what was constant across cultures that might be responsible for sex differences in science. Typical research included the early studies from a deficit perspective referred to earlier in this chapter. These focused, for example, on sex differences in cognitive abilities such as spatial visualisation [with many proposing a sex-linked genetic origin for these differences, as shown by Gray's (1981) overview] and on sex differences in mathematical ability, with claims that males' "superior mathematical ability" was due to the inherently greater male ability on spatial tasks (Benbow & Stanley, 1980, p. 1264).

These kinds of claims have been challenged by some of the more recent research on cognitive abilities. Linn and Hyde (1989), for example, used meta-analyses to synthesise the findings of a large number of studies of sex-associated differences in verbal, quantitative and spatial abilities. Because 1974 was the year in which Maccoby and Jacklin published their influential synthesis of sex differences (Maccoby & Jacklin, 1974), Linn and Hyde used that year as a benchmark for dividing their analyses into two parts, thus enabling comparisons to be made between the findings of research undertaken before and after 1974. The analyses revealed that some important changes had taken place. First, for verbal abilities, sex

differences which previously had been significantly in females' favour had declined to the point of being non-significant. Second, for quantitative abilities, sex differences in males' favour had disappeared for most measures, and those that remained were not consistent or were idiosyncratic to particular tests (for example, the quantitative section of the Scholastic Aptitude Test used in the US). Third, for spatial ability, Linn and Hyde's analyses indicated that sex differences in males' favour were declining and inconsistent, and furthermore that those differences which remained appeared to be reducing under the influence of special training.

If sex differences in science were due to sex differences in cognitive abilities, then it would be expected that they too would have declined in recent years to the same extent. Such has not been the case, however, especially in relation to participation of males and females in science. This suggests that, rather than focus on what is common across cultures that might be responsible for sex differences in science, it is likely to be more productive to focus on what varies across cultures (and across education systems) that might mitigate the sex differences in science exposed by the IEA studies. Reports emanating from research undertaken from this latter perspective surfaced at the early GASAT conferences, and indeed led the participants at the first conference to propose a conceptual framework to assist them in interpretation of the trends emerging from different cultures (Raat, Harding & Mottier, 1982). The framework was sociological in orientation. It consisted of a figure depicting three intersecting sets, illustrating the dependence of science and technology education on, first, aspects of the education system, second, the practice of science and technology and, third, the operation of sex-role stereotypes in each society. It was modified later by Parker (1992) to illustrate the relationship between gender and science and

mathematics in terms of the philosophy, aims and organisation of education; science and mathematics in practice; and society's expectations of males and females.

Such macro-level frameworks shed some valuable insights on the relationship between gender and science and highlighted the value of cross-cultural studies in this area. In this context, a number of interesting studies were undertaken. These included, for example, the study of Klainin, Fensham and West (1987) which demonstrated enhanced participation and achievement of girls in school chemistry in Thailand, a country where chemistry-related activities are part of the everyday work of females and chemistry is not stereotyped as a male subject. The frameworks also generated an awareness of the need to flesh out the prevailing macro-level studies with a more finely-grained approach which takes account of the realities of teachers and students in classrooms and schools. This latter approach, in turn, led Kahle et al (1993) to the development of a model for explaining the relationship between gender and science at the school or classroom level.

In addition to these proposed models, the number of studies of the gender/science relationship, in particular as it is affected by the portrayal, organisation and assessment of scientific knowledge by schools and school systems, has burgeoned in recent years. Kahle and Meece (1992) have provided an excellent review of many of these studies, examining factors underlying the differential participation of boys and girls in school science, discussing interventions directed at increasing the participation of girls and women in science, and analysing where further progress is needed. A number of previous syntheses also have suggested or hypothesised ways in which education could be transformed to improve the relationship between gender and science [for example Kelly's (1985, p. 149) description of a "transformative school"]. Other studies have

described attempts to bring about such transformations, as demonstrated, for example, by the scores of such studies reported at the seven GASAT conferences referred to earlier. A much smaller number of studies have presented evidence of strategies which actually have transformed education, and have highlighted collectively a number of critical features common to such strategies. It is this latter group of studies, many of which were either action research or evaluations of interventions, which is the focus of the next two sections of this chapter. The next section reviews the set of conditions which research has demonstrated are prerequisite for the success of strategies, and the following section reviews a number of areas where successful strategies have been implemented.

FEATURES COMMON TO SUCCESSFUL STRATEGIES

Earlier in this chapter, the point was made that schools and school systems can make a difference to the ways in which the relationship between gender and science develops and endures, given appropriate conditions. The research evidence for those conditions is presented here.

The earliest activities for which comprehensive and systematic evaluative information is available are those carried out in the United States during the 1970s and 1980s, aimed at improving the quality and the quantity of either or both of science and mathematics education for females. A common focus was on careers, based on the assumption that science and mathematics were "critical filters" (Sells, 1976) for entry to many scientific and technological careers. Stage, Kreinberg, Eccles and Becker (1985) estimated that as many as 600 such programs were developed and implemented during this period.

For some of the 600 programs, descriptive and evaluative data, together with judgements regarding the possible replicability and wider impact of the programs, are available. In what was essentially a meta-evaluation of these programs Stage et al (1985) focused on six categories. As demonstrated by the following list, these six categories reveal that the dominant emphasis of US programs in the the 1970s and 1980s was on giving females *more* science and mathematics, with little if any challenge to the prevailing definitions and image of science and mathematics. The categories were: (a) special classes to teach females more mathematics and science, (b) special classes to address problems faced by females, such as "math anxiety" (Mallow and Greenberg, 1982), (c) curricula designed to address special needs of females [e.g. COMETS - Career Oriented Modules for Exploring Topics in Science (Smith, 1987)], (d) teacher education programs, (e) school district-based efforts, including resource banks of materials, expertise and role models, (f) extracurricular or co-curricular activities, such as visiting programs, conferences and support networks.

The overall conclusion of the Stage et al meta-evaluation was that success in such programs is associated with three features: a strong academic emphasis (presumably seen in terms of the then prevailing definition of rigour in science and mathematics education), multiple strategies and a systems approach. Stage et al pointed out that these elements, while representing the strengths of programs for increasing females' participation and achievement in mathematics and science, also represent sound educational practice in relation to all students.

Malcom (1984) made some similar points in her report of the evaluation of 167 US programs aimed at facilitating access and achievement of females and/or minorities in school mathematics and science. The evaluation team used the following seven criteria to identify "exemplary" programs: a program's achievement of its stated

goals, its duration, its ability to attract outside support, its popularity (estimated from the ratio of applicants to places available), its reputation with local scientists from affected groups, and how readily it had been copied.

Malcom's report reiterated the need for a multifaceted approach, a point also emphasised by Kahle and Meece (1992). In addition, Malcom's analysis revealed that the exemplary projects identified by her evaluation team had five other characteristics in common, characteristics which, as shown in the following discussion, also have been found in other analyses of successful strategies.

First, Malcom emphasised that "unless programs 'for all' specifically assess the status of, articulate goals for, and directly target educational problems of females...they are unlikely to be effective" (1984, p. xiii). Later research by Harding (1991b) also lent support this point. It is apparent that making a science subject compulsory, or designating it "for all" does not necessarily result in females participating in larger numbers. For science/mathematics programs "for all" to be seen by females as genuinely inclusive of both sexes, active recruitment and encouragement of females is needed.

A second finding of Malcom's related to mainstreaming of initiatives. Although she considered mainstreaming to be both possible and desirable, she emphasised that it must be preceded by specific targetting, institutionalisation of elements critical to females' achievement and monitoring to ensure participation levels are maintained. The pitfalls of premature or unsupported mainstreaming, from a gender equity point of view, also have been demonstrated in a number of other contexts, for example in the implementation of the British Technical and Vocational Education Initiative (James & Young, 1989) and the Western Australian Unit Curriculum (Rennie & Parker,

1993; Johnston, Rennie & Offer, 1993; see also Chapter 7 of this thesis). The research evidence has demonstrated clearly that, in mainstreamed initiatives, even those with equity as an explicit goal, specific support for females is required for the equity rhetoric to be translated into reality.

Malcom's evaluation also showed the fundamental importance of systemic support for equity initiatives. Again this point has been supported by other evaluations. Harding (1991b), for example, has demonstrated the ultimate abandonment of some UK school-based projects which were dependent on single, unsupported teachers. Conversely, Parker, Harding and Rennie (in press) have described the success of the McClintock Collective in the Australian State of Victoria and the manner in which this group, in a climate of government support, and clear government policy statements emphasising the need for equity in science and mathematics education, grew from a small network of 12 female science teachers to an extensive State-wide network of over 400 teachers, producing professional development materials which received international recognition.

The fourth feature to emerge from the evaluation studies of Malcom was the need for strong leadership and committed teachers, a point also demonstrated in the outcomes of the Girls Into Science and Technology (GIST) action research project, implemented in the UK in 1980–1983 (Whyte, 1986). The GIST project's approach to working with teachers focused on the development and implementation of non-sexist curriculum materials and teaching strategies, with the aim ultimately of increasing the enrolment of girls in physical science and technical subjects. At the end of the project's three years, it was found that although, across all 10 targetted schools, there were no significant changes in the pattern of subject choice, or improvements in girls' attitude towards science, some individual schools did show improvements.

These were the schools in which administrators were prepared to allocate resources to the project, and teachers were committed to the project and prepared to take leadership roles.

A fifth point made by Malcom (1984) and supported strongly by other evidence [e.g. Asekog (1986), from a Swedish perspective] concerned the long-term effects of initiatives. Malcom noted that, while there were many instances of the short-term, relatively superficial success of one-off initiatives for motivational, awareness-raising or morale-boosting purposes, the initiatives needed to be sustained in order to be successful in any meaningful, long-term sense.

In summary, then, research has demonstrated a set of conditions which appear to be prerequisites for the success of school- and school system-based initiatives in the area of gender and science. Six major prerequisites, which appear to be of enduring significance well beyond the 1980s, when they were first articulated by Malcom, are the need for

- a multifaceted approach
- specific targetting (and the concomitant recognition of the limitations of programs designated "for all")
- avoidance of premature mainstreaming (or, alternatively, provision of specific equity support for initiatives which are mainstreamed)
- systemic support
- strong and committed leaders
- programs to be sustained in the longer term.

These six points, particularly those concerned with systemic support and initiatives "for all", are especially important in the context of much of the research reviewed and reported in this thesis. A possible seventh requirement for a successful program, namely, the strong "academic" emphasis (defined in terms of conventional, academically rigorous

science and mathematics) as identified earlier by Stage et al (1985), is perhaps more contentious in the 1990s than it was in the 1970s. As is shown in Chapter 5, the concept of what constitutes academically rigorous science has been challenged from a number of directions and remains in need of considerable clarification.

THE PROBLEM: THE MASCULINE IMAGE OF SCIENCE

The concept of the masculine image of science was central to the analysis conducted in this study of areas where schools and school systems appear to have made a difference to the relationship between gender and science. The dimensions of this masculine image are now well established. Since the early work of Mead and Metreux (1957), others have continued to demonstrate the ways in which science and scientists, particularly in the physical sciences, are perceived by people of many different ages and in many different cultures to be masculine (Chambers, 1983; Kahle, 1989; Maoldomhnaigh & Hunt, 1988; Mason, Kahle & Gardner, 1991; Schibeci, 1986; Schibeci & Sorensen, 1983). This work has been reconceptualised by Kelly (1985) in a highly original and insightful paper where she argued that there are four ways in which schools contribute to the construction of this masculine image of science: first, the disproportionately large numbers of males who study, teach, and are identified as practitioners of science; second, the masculine bias of the presentation and packaging of curriculum materials; third, the male-oriented patterns of classroom interaction; and, fourth, the intrinsically masculine world view embodied in the type of thinking commonly labelled "scientific" (1985, p. 133).

Three dimensions of Kelly's schema, namely, the dimensions related to "packaging", "practices" and "world view of science" provided

the structure for the analysis carried out in this study. With the advantage of being able to draw on the additional research which has taken place since 1985 and of the theoretical insights presented in Chapter 2 of this thesis, the analysis presented here was able to expand on Kelly's review in four significant ways. Three of these ways are discussed in this chapter. The first concerns some additional senses in which schools have been shown to contribute to the masculine image of science, through aspects of packaging and practices. The second concerns the transformation of schools to make the practice of science education more gender-inclusive, a transformation which was mainly hypothetical in 1985, but which can be demonstrated in much more real terms in 1993. The third concerns the analogy between Kelly's everyday concept of "packaging" and Bernstein's (1971a) concept of classification and similarly, between Kelly's concept of "practices" and Bernstein's concept of framing. The fourth, which is discussed in the next chapter, concerns more theoretical issues related to the still emerging feminist perspectives on the genderisation of science, .

CHANGING THE MASCULINE IMAGE

The Packaging

Language, examples and illustrations

The instructional materials used in science classrooms (including textbooks, films, filmstrips, records, tapes, videotapes, television programs and computer software) have been shown to carry implicit messages about the relationship between gender and science, messages which reinforce the masculine image of science. In their own extensive, empirical research, and in a major meta-analysis, Schau and Scott have demonstrated that it is possible to change this masculine image by

providing more sex-equitable materials (Schau & Scott, 1984; Scott & Schau, 1985). Reviewing nine studies, they found that when materials used male generic language (i.e. "he" and "man" to refer to people in general, or to an individual when the sex of the person is unknown or irrelevant), students of all ages and teachers at both primary and secondary school levels frequently thought of males, especially when the students and teachers themselves were male or when the content was related to typically male occupations or activities. When gender-unspecified language was used (e.g. substituting "people" for "men", or changing "he" to "they"), some students and teachers assumed more gender-balanced referents, although others (especially males) continued to make connections to males or to people of their own sex. Generally gender-balanced associations, however, resulted from materials using gender-specified language (referring explicitly to both females and males or to a specific female or male).

In a further review of 21 studies, Schau and Scott (1984) showed that sex-biased materials (i.e. those which portray more males than females as main characters, portray males and females in stereotypical roles, portray females more often than males in derogatory roles and/or use male generic language) contributed to sex-typed attitudes. Conversely, however, sex-equitable materials (portraying a variety of roles for males and females, and emphasising gender-specified language) contributed consistently and persistently to more flexible sex role attitudes. Further, the effect increased with increased exposure to sex-equitable materials. It did not appear, however, to be generalised to situations or content not included in the materials, indicating that materials need to be targeted specifically at whatever change is desired (i.e. if the aim is for students to make less sex-stereotyped occupational

choices, then the materials need to show females and males in non-traditional occupations).

Overall, Schau and Scott's meta-analysis has provided a valuable guide to educators in all subject areas. Although there were many limitations to the studies they reviewed, including the lack of a theoretical base (as noted earlier, in relation to research on gender and science education), their conclusions were unequivocal:

Sex-equitable materials can improve the learning experiences of both male and female students. They assist in developing gender-balanced associations and more flexible sex role attitudes. They are not rejected by students and are sometimes preferred.

(Schau & Scott, 1984, p. 191)

Science topics

More specifically in relation to the content of science materials, other research has demonstrated the importance of the actual topic addressed in the materials, and the beneficial effects of including illustrations, examples and applications which connect to the background experiences of both females and males (e.g. Whyte, 1986). The success of topics with social and environmental connotations has been noted especially in this regard. For example, Jan Harding's *Chemistry from Issues* materials (Harding, 1985) and the PLON materials in The Netherlands (Jorg & Wubbels, 1987) were especially successful in increasing girls' interest in the physical sciences. Clearly, the relationship between this increased interest in science and girls' participation and achievement in the long term needs further research. There is general agreement, however, that even if increased interest were the sole outcome of these initiatives to include social and environmental issues in science materials, it is a valuable outcome in its own right.

In the context of the theoretical framework introduced in Chapter 2 of this thesis, an increased emphasis on social and environmental issues can be seen as a shift towards a curriculum which, in Bernstein's terms, is a less strongly classified, integrated code curriculum. Whether this has implications also for the status and perceived academic rigour of curricula with this emphasis was a matter investigated in this study.

Differential Course-taking

In 1977, Fennema and Sherman carried out an analysis of previous research which claimed to have established male superiority in mathematics achievement. They pointed out that, typically, such research had not controlled for one of the most important relevant variables, namely, the amount of previous study of mathematics. As a result of their analysis, they developed their "differential course-taking hypothesis", proposing that the sex differences claimed in many studies were an outcome of the greater number of mathematics courses studied and longer time spent on mathematics by boys compared to girls.

There has been considerable debate about this hypothesis. Benbow and Stanley (1980) rejected it as a possible explanation for what they described as "huge" sex differences in mathematical aptitude and achievement. They claimed that their own data, from intellectually gifted students' mathematics scores on the Scholastic Aptitude Test (SAT) did not support the hypothesis. They remained firm in their belief that superior male ability, of both endogenous and exogenous origin, was responsible for the higher scores of males compared to females. Pallas and Alexander (1983), however, analysing the same SAT results for a more representative sample of students, and controlling in their analysis for previous mathematics coursework, found that the male/female

difference in performance, while it did not disappear completely, was far smaller than that found by Benbow and Stanley.

Although the differences in the interpretations of these two groups of researchers appear to be irreconcilable (Benbow & Stanley, 1983; Alexander & Pallas, 1983), other research has provided support for the differential course-taking hypothesis. Moss (1982) in her analysis of data from all Australian States, found that, when allowance was made for three factors – father's occupation, age of student and hours spent by student in learning mathematics – there was no evidence of sex differences in mathematics achievement at the Year 12 level. Similarly, research in Western Australia on mathematics achievement (Parker, 1984; Parker & Tims, 1993) and on science achievement (Parker & Offer, 1987; see also Chapter 7 of this thesis) has provided support for the Fennema and Sherman hypothesis. These kinds of findings suggest that girls can do just as well as boys at subjects such as mathematics and science, if they are given (and if they take) the opportunity to study these subjects to the same extent as boys. A problem arises, however, with a strongly classified curriculum structure which requires students to choose one subject or another. The evidence suggests that curriculum structures which allow students the opportunity to choose whether or not to continue with mathematics and science have potential to disadvantage girls in terms of the girls' ultimate science/mathematics achievement. This issue has not been addressed comprehensively in previous research, but was part of the theory-testing phase of the study reported here.

The Practices

"Typical" teaching/learning strategies in science classrooms

The teaching/learning strategies used by science teachers have been researched extensively. The stereotype science education of the 1960's and 1970's is described well in the literature. In Bernstein's terms, it was a typical strongly framed curriculum. Malcolm (1989, p. 214), for example, described a model in which the teacher, as expert, controlled the content, the process, and the pace of lessons with very little room for negotiation on the part of the students. He referred to the rather unkind and certainly unrealistic metaphors associated with this model: the learner as the *tabula rasa* on which the teacher wrote, or as the plant which the teacher fertilised and watered. Also focusing on the 1960's and 1970's, Fensham (1988a, p. 11) listed a number of characteristics of the kind of science teaching considered most worthwhile at that time. Rote recall, abstract concepts and quantification were the central thesis of these characteristics. Human communication and social reality were their antithesis. In a similar vein, Driver (1988, p. 138) by implication portrayed a model in which learners were viewed as passive, knowledge was seen as remote from the learner's experience and unproblematic, teachers were an inert vehicle for conveying knowledge, and curriculum was prescribed tightly and "teacher proof".

The emergence of alternative teaching/learning strategies

During the 1980s, alternative strategies for teaching and learning science, strategies which were in fact typical of Bernstein's weak framing, began to emerge from two sources. One source was the research on constructivist approaches (Driver & Bell, 1986; Gunstone, 1988; Osborne & Freyburg, 1985) which revealed that students' prior everyday knowledge was of fundamental importance to the way they learned science. From this perspective, Driver (1988) and others emphasised the importance of interpersonal negotiation, human interaction and

discussion as part of teaching/learning strategies in science classrooms. At approximately the same time, but from a strongly empirical and experiential base, teachers concerned about the situation of girls in science began to develop and implement strategies which were variously described as "counter-sexist", "non-sexist" (Whyte, 1983), or "girl-friendly" (Smail, 1984). These strategies, again, typified Bernstein's weak framing, placing great emphasis on language, active participation of students and meaningful contexts. There is mounting evidence regarding the possibilities and limits of these constructivist or girl-friendly strategies, as discussed in the following sections.

Student-student interaction in science classrooms

Student-student interaction has been the focus of much recent research. As indicated above, this has led to increased recognition that much of what transpires in schools and classrooms is of a competitive, strongly framed nature, and that not all students, particularly not all female students thrive in such an environment. Research has indicated consistently that females prefer and take a more active role in science and mathematics when the pedagogy is more weakly framed (Baker, 1990; Eccles, 1989; Johnson & Johnson, 1987; Kahle, 1990; Owens & Barnes, 1982; Smail, 1984). An increasing body of evidence has indicated that interactive, activity-based approaches to science teaching are associated with girls' increased enjoyment of science and increased achievement in science [e.g. Danzl-Tauer (1990) quoted in Kahle and Meece (1992)]. Cooperative learning strategies also have been shown to have a positive effect on science students' (especially female students') achievement and attitude (Eccles, 1989; Okebukola, 1985), although some research has cautioned that, unless group interactions are monitored sensitively,

cooperative learning actually can reinforce gender stereotypes (Bossert, 1988-89).

Teacher-student interaction

The predominant pattern of teachers' interaction with their male and female students is now well established. Kelly's (1988) meta-analysis of 81 studies of teacher-pupil interaction has provided the most compelling evidence in this regard. Her conclusion was that "it is now beyond dispute that girls receive less of the teacher's attention in class, and that this is true across a wide range of conditions" (p. 20). She showed also that, although teachers trained in sex equity are more likely to distribute their attention equally between the sexes, science is one of the areas in which females tend to be particularly under-involved in lessons. Although research has not established a clear causal link between patterns of classroom interaction and sex differences in achievement and attitude to science, studies carried out in mathematics education have indicated a weak overall relationship between student-teacher interaction patterns and mathematics-related attitudes and future study plans [Stage et al (1985) reviewing the work of Eccles and others]. These studies have indicated also that the impact of a single salient teacher on female students' attitudes to mathematics can be large if the teacher provides the girls with active encouragement, through exposing them to role models, praising them sincerely for high performance and giving them explicit advice regarding the value, especially the career-related value, of mathematics.

The research of Gaskell, McLaren, Oberg and Eyre (1993) in Canada also has confirmed that it is important for teachers, in their interaction with students, to link mathematics and the physical sciences to real-world opportunities and careers. In their rigorous and comprehensive

study Gaskell et al compared schools in which participation in senior mathematics/physics was high with those in which it was low.

Although the study revealed few clear differences between the two categories of schools, it did show that staff in "high participation" schools provided active encouragement to both girls and boys to enrol in senior mathematics and physics, in order to keep open all possible career options.

In this context, Kahle (1988) has reported also that biology teachers successful in encouraging both females and males to continue studies in science were those who, amongst other things, offered encouragement and career-related advice. Interestingly, the exemplary teachers in Kahle's study emphasised laboratory work and discussions groups, quizzed their students weekly, stressed creativity and basic skills, used a variety of resources, and, above all, made their classrooms into attractive, lively environments with posters, projects, live plants and animals.

Once again, in Bernstein's terms, these successful strategies, with their informality and their emphasis on real-world examples (specifically careers), are typical of a more weakly framed curriculum and, once again, questions tend to be raised about the perceived status and rigour of such a curriculum.

Students' Attitudes

Sex differences in attitudes to science also have been investigated in many studies. Several large-scale studies [e.g. the IEA studies referred to earlier in this chapter, and analyses of the National Association for Educational Progress (NAEP) data (Mullis & Jenkins, 1988; Nelson, Weiss & Capper, 1990)] have reported that males' attitudes to science are more positive than those of females. Other review studies have reported relatively small sex differences in overall attitude to science (e.g. Fleming

& Malone, 1983; Haladyna & Shaughnessey, 1982; Steinkamp & Maehr, 1983, 1984; Wilson, 1983). However, in the syntheses carried out by Steinkamp and Maehr (1983, 1984), when science was categorised according to biology, physics or chemistry content, females were more positive than males towards biology and chemistry, but less positive towards physics. Further, when attitude to science was divided into various categories, boys were found to have stronger self-concepts of science ability than girls, but sex differences for interest, importance and enjoyment were negligible. Other studies have suggested also that gender effects in attitude to science can vary with age, with geographic location of school (Matyas, 1984), with ethnicity (Campbell, 1991) and with socio-economic background of students (Steinkamp & Maehr, 1984). In the latter context, Kelly (1988) found that low socio-economic status was associated with stronger sex-stereotyping by girls, which in turn was associated with lower achievement in science, poorer attitude to science, and choice of biology rather than physics.

From the point of view of schools and school systems, although a recurring factor in studies of attitude towards science has been its close association with males' and females' typical patterns of out-of-school science-related activities (Johnson, 1987; Kahle & Lakes, 1983; Sjoberg & Imsen, 1988; Smail & Kelly, 1984), some research has shown that science attitudes can be changed by targetted activities carried out by, or under the auspices of, schools or school systems. Two identical studies carried out in Australia and the US (Kahle, Anderson & Damjanovic, 1991; Rennie, Parker & Hutchinson, 1985) have demonstrated this point well. In both studies, an inservice program for science teachers, which focused on the teaching of an electricity topic in ways that emphasised real-life applications familiar to both girls and boys (again a more weakly framed approach to the topic than that taken traditionally), was associated with a

decrease in sex-stereotyping of students' (especially girls') attitudes towards science. [The model referred to earlier in this chapter, for conceptualising influences on the gender-science relationship at the school and classroom level (Kahle et al, 1993), was developed from empirical research carried out in these two studies.]

Method of Measurement of Science Achievement

Increasingly, in recent years, it has been recognised that decisions about the form and organisation of assessment in any education system are not neutral decisions (P. Murphy, 1993). They now are seen as reflecting strongly what is valued by the system, and as defining what is taught, what is meant by "achievement" and which students succeed. In this climate, research on the interaction of gender with the format and context of different forms of assessment has provided considerable insight into the ways in which schools and school systems can structure assessment to be fair and equitable to all students.

Format of assessment tasks and mode of assessment

During the past 20 years or so, researchers in different parts of the world have shown intermittent interest in contrasting males' and females' performances on different modes of assessment. Some previous research has suggested a pattern in which males appear to have an advantage on external assessment (particularly in association with multiple-choice tests) while females appear to have an advantage on school-based or classroom-based continuous assessment (particularly in association with assessment tasks where a more extended response is required). Although conceptually the two variables (format of item and mode of assessment) are quite separate, frequently they become confused in practice, because research on large-scale data sets typically involves

State-wide or nation-wide external tests, which happen also to comprise mainly multiple-choice items [such as, for example, the Scholastic Aptitude Test (SAT) administered to pre-college students in the US].

Research focused more on the item format issue typically has investigated situations where a formal examination paper (i.e. a strongly framed, collection code assessment task, in terms of the framework developed in Chapter 2,) has both multiple-choice and extended-response sections. For example, in relation to the English O-Level examinations, a male advantage on multiple-choice items and a female advantage on extended-response items has been reported by Harding (1979) for Nuffield Science, Wood (1978) for English and R. Murphy (1982) for a wide range of subjects. More recently, a similar pattern has been confirmed by Bell and Hay (1987) in an investigation of the effects of different item formats in English language examinations in Western Australia; Bolger and Kellaghan (1990) using data from Irish national tests in mathematics, Irish and English; Mazzeo, Schmidt and Bleistein (1989) for US Advance Placement Tests; the Victorian Curriculum and Assessment Board (VCAB, 1988, 1989) for Physics at Year 12 level in the former Victorian Certificate of Education (VCE); and Whitehouse and Sullivan (1992) for Year 12 science subjects in South Australia. The most recent analysis of results from the first year of the new VCE Physics, reported by Hildebrand and Allard (1993), also confirmed this pattern and, in addition, drew attention to the manifestation of higher achievement by females in the continuous, more school-based assessment model which is now part the VCE system.

Research focused more on the mode of assessment aspect dates back to the time when the English O-Level examination system enabled comparisons to be made between students' achievement on externally administered, formal examinations (i.e., strongly framed, collection code

assessment tasks) and their performance on less formal tests administered by their school (i.e., more weakly framed, integrated code assessment tasks). A number of analyses of males' and females' results under this system suggested that males scored better on external tests while females scored better on school-administered tests [Forrest (1971) and Forrest & Smith (1972), cited in R. Murphy (1982)]. This pattern was confirmed by the findings of similar analyses of British data reported later by Linn (1973), Nuttall, Backhouse and Willmott (1974) and Willmott (1977). In the US, a similar trend emerged: at the upper levels of schooling, students' results on school-based assessments, indicating higher achievement by girls than boys (Ellis & Peterson, 1971) were contradicted by the results of standardised tests, indicating higher achievement by boys than girls (Finn, 1980; Finn, Dulberg & Reis, 1979). All of these analyses, however, focused on data from only one year. None of them was able to establish whether the gender effect of different modes of assessment was a systematic trend, occurring over a considerable period. As is shown in Chapter 8, the study reported in this thesis was able to address this question and, in addressing it, reveal a systematic effect over eight years, with more strongly framed assessment favouring males and more weakly framed assessment favouring females.

Context of assessment tasks

Some recent analyses of sex-related differences in science performance have suggested that performance differences can be explained in part by the sex-related differences in out-of-school experiences referred to earlier in this chapter. Research on the large-scale test conducted by the British Assessment of Performance Unit (APU) (Johnson, 1987; P. Murphy, 1988, 1991) established that, at ages 11 and 13, irrespective of the criteria being assessed, there were sex differences in

science achievement which reflected areas in which boys and girls typically had greater experience or interest. Overall, females did better on items concerning health, reproduction, nutrition and domestic situations, while males did better on items concerning building sites, race tracks, spare parts catalogues and electricity. Further support for this explanation came from Erickson and Erickson (1984) and Bateson and Parsons-Chatman (1989) who examined, respectively, the multiple-choice items in the 1976 and 1986 provincial assessments of science achievement in British Columbia. These researchers compared items for which sex-related differences were small with those for which they were large, and concluded that, in many of the latter, the context (as distinct from the science concept being tested) was male-oriented (i.e. the items were set in a context which was more likely to be familiar to males than to females). This raises the question of whether a student is more likely to omit or misunderstand an item if the context of the item is alien to her/him, a question which is being investigated in ongoing research reported by Rennie and Parker (1993). It suggests also that Bernstein's concept of strong and weak framing really is concerned with different framing. In this sense, the use of the adjectives strong and weak is problematic. The kind of framing which appears to advantage males has been labelled strong, while that which advantages females has been labelled weak. As is shown in Chapter 5, semantically, this kind of labelling can have far-reaching, debilitating consequences for females.

Explanations for apparent gender bias in testing

In attempting to explain the pattern of differential performance described above, several hypotheses have been advanced. None, however, has been substantiated conclusively. Some hypotheses focus on a perception of females as typically better at written work, in terms of

content, length and presentation. In relation to this focus, however, R. Murphy's (1982) hypothesis that females' allegedly more highly developed written skills would advantage them when dealing with extended response formats did not stand up when tested empirically by Bolger and Kellaghan (1990). From a different perspective, P. Murphy (1988) focused on gender differences in ways of constructing the world, suggesting that females tend to reflect on the broader context of a multiple-choice item, and that because of this, the ambiguities embedded in most sets of distractors tend to invalidate multiple-choice items as a means of testing females' knowledge. Yet other researchers have focused on sex-differences in tendencies to guess or take risks. For example, Hanna (1989) in Ontario and Ben-Shakhar and Sinai (1991) in Israel found that females were more likely than males to omit items when they were not certain of the answers; in other words, females were less likely than males to guess the answers. Forgasz and Leder (1991), however, have demonstrated that it is difficult to generalise about gender differences in risk-taking behaviour, thus casting doubts also on this hypothesis.

From an explanatory or theoretical perspective, the situation remains confused. More than a decade ago, Kelly and Nihlen (1982) noted the confusion and unresolved contradictions in this area. This is still the case. Increasingly, researchers are realising that there are no simple answers to the questions which they are posing. For example, from their study of differential item functioning, Scheuneman and Gerritz (1990) concluded that the multiple-choice format, as such, does not disadvantage females, but rather that a combination of item characteristics, each with a small effect related to the "weaknesses" and "strengths" of males and females, produces a cumulative effect manifested as the pattern such as that described here. A review by

Bannister (1988) also has suggested that a complex of factors, rather than a single cause, is responsible for the gendered pattern of outcomes of different assessment tasks, and that this phenomenon is addressed best by focusing on how pedagogy produces this gendered pattern, in particular on "the field of assumptions about what counts as science and as learning in science" (Yates, 1993, p. 55). This places the focus, again, on aspects of Bernstein's collection and integrated codes, especially on the legitimation of the collection code through formal, external examinations, and on the greater perceived legitimacy of external examinations and standardised tests as a mode of assessment (Black, 1994; Broadfoot, 1979).

Teacher Expectations – Implications for Pedagogy and Coding

There is a vast literature, spanning many subjects and countries, reporting research on teacher expectations. Kahle et al (1993), summarising the studies which focus on science (Benz, Pfeiffer & Newman, 1981; Shepardson & Pizzini, 1992; Whyte, 1986; Worrall & Tsarna, 1987) have reported that teachers, without specific equity training, tend to believe that neither high achievement nor the study of science is consistent with the feminine role. Kahle et al reported also that studies focusing on the relationship between teacher expectations and student achievement indicate that teachers are remarkably accurate in their predictions of student achievement, especially school-based grades. Jussim (1990), in his synthesis of many of these studies, found that "not a single naturalistic study has identified a single condition under which teachers' expectations cause student achievement more than student achievement causes teacher expectations" (p. 20). Nevertheless, he upheld the importance of teacher expectancy effects, particularly for students who would be especially vulnerable because of lack of confidence or an unfamiliar situation (conditions which other research

indicates would apply to females in traditional, collection code science classrooms). In the latter context, the importance of classification and framing again becomes evident, as does the importance of understanding that, as emphasised in the Kahle et al (1993) model referred to earlier, the beliefs and ideologies of both teachers and students can be important determinants of the students' ultimate educational achievement and life chances.

Summary and Comment: Gaps in the Research

The review of research presented in this section has revealed that, although research to date has been comprehensive, there are nevertheless some major gaps in knowledge of ways in which policy and practice in schools or school systems might make a difference to the relationship between gender and science. In some areas, identified throughout the section, much more evidence is needed, in much finer detail than is available at present, focusing, for example, on socio-economic or ethnic variables which interact with gender. As many researchers have noted, much previous work appears to assume that all boys or all girls are the same. Such an assumption of homogeneity is unwarranted. There is large variation amongst girls and amongst boys, arising from background factors, which rarely have been taken into consideration by researchers.

The literature review also has revealed two notable absences from previous research. First, there is no reported research on the gender effect of changes in individual science subjects at the senior secondary level. Second, other than some preliminary analyses of Victorian and UK data (Hildebrand & Allard, 1993; Murphy, 1993), there is no research on the gender effect of changes in system-level curriculum and assessment

policy in science at the senior secondary level. These two areas were explored in the present study, as reported in Chapters 6–8 of this thesis.

Despite these gaps, however, previous research has contributed much to an understanding, from practitioners' perspectives, of what a more effective science curriculum for girls might look like. The final section of this chapter summarises the major characteristics of such a curriculum and the manner in which it maps on to the initial theoretical framework developed in Chapter 2.

THE IMAGE AND CODING OF GENDER-INCLUSIVE SCIENCE

In expanding Kelly's (1985) analysis of the ways in which schools construct science as masculine, the part of the present study reported in this chapter focused on two of her dimensions, namely, packaging and practices. At the same time, the analogies between Kelly's packaging/practices dimensions and Bernstein's (1971a) classification/framing dimensions, as shown in the theoretical framework developed in Chapter 2. The image of a more gender-inclusive science which emerged from this part of the study is one of a curriculum which

- in terms of Kelly's packaging (or Bernstein's classification)
 - (a) has content which is sex-equitable in its use of language and includes illustrations and examples which have meaning in the lives of both females and males;
 - (b) has content which emphasises social and environmental issues; and
 - (c) is structured in a way which ensures that both females and males study a balance of physical and biological sciences and are not required to choose one or the other branch of science during their schooling,

thus, in all three instances, representing a shift towards weaker classification;

- in terms of Kelly's practices (or Bernstein's framing)
 - (a) has pedagogy emphasising interpersonal negotiation, human interaction, language, active participation by students and real-life contexts;
 - (b) has school-based, informal assessment procedures, with relatively open-ended tasks drawing on contexts which are familiar to both males and females; and
 - (c) pays attention to students' self-awareness of the extent to which their education-related decisions and experiences are socially constructed, and are the products of hegemonic influences on themselves and their teachers,

thus, again in all three cases, representing a shift towards weaker framing.

Overall, then, in terms of the theoretical framework developed in this study, a shift to a more gender-inclusive science curriculum can be seen as a shift away from a collection code curriculum, towards a more integrated code curriculum.

SUMMARY

This chapter began with a statement that, given appropriate conditions, factors over which schools and school systems have control make a difference to the ways in which the relationship between gender and science develops and endures. This statement was substantiated by research demonstrating the effect, on the gender/science relationship, of changes in certain aspects of educational policy and practice. The literature review revealed also two notable absences from previous

research. These are, first, the absence of research on the gender effect of changes in individual subjects at the senior secondary level and, second, the absence of research on the overarching effect of changes in curriculum and assessment policy at the senior secondary level.

The major outcome of the review presented in this chapter, however, was that it enabled an image of a more gender-inclusive science to be drawn. In this sense, it has moved well beyond most previous analyses, which have tended to hypothesise about the characteristics of a gender-inclusive curriculum, rather than to present evaluative evidence about these characteristics. With reference to the theoretical framework developed in Chapter 2, the image drawn as a result of this analysis was characterised as a relatively integrated code curriculum. The review raised also a question regarding the extent to which such an integrated code curriculum is perceived, in Young's (1971) terms, as a lower status and less rigorous curriculum. As shown in Chapter 6, this question was pursued systematically in the theory-testing phase of this study, through exploration of one of the gaps in the research identified above, namely, the gender effect of changes in individual science subjects at the senior secondary level.

Chapter 5

FEMINIST SCHOLARSHIP ON GENDER AND SCIENCE

PURPOSE AND OUTLINE OF THE CHAPTER

As foreshadowed in Chapter 4, this chapter focuses on the fourth dimension of Kelly's (1985) schema depicting the ways in which schools construct science as masculine. This dimension concerns "the intrinsically masculine world view embodied in the type of thinking commonly labelled 'scientific'" (p. 133). The purpose of the part of the study reported in this chapter was to develop a theoretical view of what a more gender-inclusive science might look like, and to consider this image in terms of the empirical view developed in Chapter 4 and the theoretical framework developed in Chapter 2.

As indicated previously, up until very recently, most researchers of gender issues in science education have operated in the absence of an integrating theory. Many also, particularly in the early years of research on gender and science, operated in situations which were remote, both physically and intellectually, from the growing body of more theoretical work on the gender/science relationship carried out by postmodernist feminist scholars, work which itself was somewhat remote from that of curriculum theorists working from a sociology of knowledge perspective. As noted earlier, the bringing together of the empirical and the theoretical perspectives was an important contribution of this study, and was also, of course, a necessary intermediate step towards achieving part

of the major purpose of the study, namely, the linking of these combined perspectives to theories emanating from the sociology of knowledge.

This chapter focuses specifically on the work of scholars who are part of the postmodernist feminist critique of science. The term postmodernist is used in this thesis in the sense outlined by Lather (1991). Postmodernism is seen as defined by (a) shifts in forms of authority (for example from the modernist secular humanism, based, above all, on reason, to more participatory and pluralistic structures); (b) shifts in material conditions (for example from the bureaucratic rationalisation of the industrial age to micro-electronic global capitalism); and, (c) shifts in the conception of the individual (for example from one shaped, in a predetermined and "rational" sense, by education, to one who continually constructs her/his own meanings from educational experiences). These shifts are seen as occurring in association with, amongst other developments, the global uprising of marginalised groups, including women and people of colour.

The chapter begins with a discussion of the postmodernist feminist critique of science which has emerged during the past decade or two. It provides an overview of the major strands within this critique, then focuses specifically on the strand concerned with the definition of science. Within this context, it deals in considerable detail with the work of Keller (1978, 1982, 1983, 1985, 1989) and discusses the contributions of other post-modernist feminists in relation to specific aspects of Keller's work on the definition of science. Following a discussion of the place of dualisms and of the need for dualisms to be interpreted as complementary rather than oppositional, it presents a summary image of gender-inclusive science distilled from the postmodernist feminist critique of science. The concluding section of the chapter then translates this image into a picture of a gender-inclusive school science curriculum, indicates the extent to

which this picture mirrors the empirically established image (developed in Chapter 4) and the ways in which the combined theoretical/empirical picture maps on to the theoretical framework developed in Chapter 2.

THE FEMINIST CRITIQUE OF SCIENCE

Background

In a sense, the postmodernist feminist critique of science has emerged as a subset of the sociology of knowledge. Initially this critique filled a gap in the work of scholars who were purporting to study the relationship between science and society. As Schiebinger (1987) pointed out, until the 1970s, although theorists exploring the social origins of modern science looked at participation in science by people of different religion, class and age, they tended to ignore the question of gender. Merton (1973), for example, in his treatise on the sociology of science, drew attention to the 62 percent of the initial membership of the Royal Society who were Puritan, but neglected to mention that 100 percent of the members were male.

Since the mid-1970s, however, feminist scholars have focused increasingly on the ideologies, politics and epistemologies of traditional science and, in so doing, have generated and addressed a range of questions, many of which have considerable significance also in relation to class and race biases of traditional science. The study reported here was informed by and enriched by the emerging answers to "the 'science question' in feminism" (S. Harding, 1986). As indicated in Chapter 1, this study was based on Sandra Harding's view that "gender is a fundamental category within which meaning and value are assigned to everything in the world, a way of organizing social relations" (1986, p. 57). Like Code

(1993), it began not only with the assumption that gender must be put in place as a primary analytic category, but also that

it is impossible to sustain the presumption of gender-neutrality that is central to standard epistemologies: the presumption that gender has nothing to do with knowledge, that the mind has no sex, that reason is alike in all men, and man 'embraces' woman.

(Code, 1993, p. 20)

In particular, this study focused on research bearing on the definition of science. It took seriously the warning of Young (1971b) that such definitions should not be taken as given, for "what 'does' and 'does not' count as science depends on the social meaning given to science, which will vary not only historically and cross-culturally but within societies and situationally" (p. 21). It recognised how important it is for women, as well as men, to have a role in defining science, because, as Frye (1983, p. 82) has pointed out, "*definition* is another face of power". As Ginzberg (1989) has reminded us, part of the work of feminists has been to claim women's right to participate in the making of meaning – to apply the term "scholarship" to studies undertaken by and for women, and to have the everyday activities of women recognised as legitimate "work" in a political and economic sense. In this study, an interrogation of the definition of "science" and its redefinition to include women's ways of knowing were activities entirely consistent with this important contribution of feminist scholars.

Mapping the Territory

Scholars focusing on science and gender have come from many different disciplines and have taken many different approaches to their studies. Further, as Sandra Harding (1993), amongst others, has pointed out, there are many different feminisms. Within this highly diverse

context, at least three scholars (S. Harding, 1986; Rosser, 1989; Schiebinger, 1987) have attempted to map the various strands within the literature. Their analyses have shown that, generally, studies fall into one of four major categories. One of these categories, concerned with the institutionalised, structural barriers to women's participation in science, has been explored, from an educational perspective, in Chapter 4 of this thesis. The other three categories are explored in this chapter, because they have produced research which has considerable potential to inform a theoretical definition of gender-inclusive science.

1. The "Her-Story" of Science

The first category embraces what could perhaps be called the "her-story" of science, as distinct from what O'Brien (1981) has termed "male-stream" history. Typified by the work of Margaret Rossiter (1982), it documents the previously obscured, undervalued and devalued contribution of women to science. It highlights the gendered nature of knowledge, in that women's activities and discoveries in areas such as horticulture and chemistry were not defined as science, although men engaging in similar kinds of activities, from a less practical or domestic point of view, were accepted as "scientists". It points to the need, not only for a broader definition of "science", but also for a recognition of the value system centred on the concept of gender. It draws attention also to the work of the women scientists who have been successful in traditional science, and of the many whom Rosser (1989, p. 4) called the "lost women of science", and it makes the names and contributions of all of these women accessible.

2. "Scientific" Definitions of Women

In the second category are critiques of the studies of "scientific" definitions of women's nature, studies which emphasise differences between men and women, and studies that trace these differences to immutable biological differences. As Schiebinger (1987) noted, such studies date back at least to Aristotle and the argument that women's weaker nature justified her inferior social status. More recently, these studies have been represented in the work of the craniologists and the arguments of the social Darwinists. The former, as described, for example, by Gould (1981), linked an alleged male intellectual superiority to males' heavier brains, while the latter, as explained by Morgan (1972) alleged that woman was man whose evolution had been arrested in a primitive stage. There also have been, as indicated by Sayers (1982) in her critical review of the area, many who either argued or assumed that women's intellectual gains could only be made at great cost to their reproductive capacities, and many others who sought to provide "scientific proof" of women's inferior nature through research on hormones or on brain lateralisation.

Several critiques of these "uses and abuses of biology", as Sandra Harding (1986, p. 21) called them, demonstrate the value-laden nature of the research. As noted by Rosser (1989, p. 7), these critiques have revealed flaws associated with, for example, poor experimental design, assumptions based on limited experimental data, and unwarranted extrapolation of data from rodents to humans. Importantly, many of the critiques have been carried out by people who are scientists in their own right [for example the neurophysiologist Bleier (1984), the biologists Birke (1986a, 1986b), Hubbard and Lowe (1979) and Lewontin (1984) and the mathematical biologist Keller (1985)]. These scientists have been joined by historians of science such as Fee (1976) and Haraway (1981) in "lifting

the argument about sex differences out of the realm of 'pure' science and placing it within its social context" (Schiebinger, 1987, p. 327). Together these researchers have been able to demonstrate the lack of validity of assumptions about the value neutrality of science, and the lack of validity of arguments which used anatomical differences between the male and the female body to justify social and educational agendas, agendas which ensured that males retained privileged access to scientific knowledge and the practice of science.

3. The Definition of Science

As indicated at the outset of this chapter, of all the strands of feminist studies, it was the third category which was the most relevant to this study. This is the strand addressing the definition of science and the ways in which the definitions of "science" and "not science", in terms of both content and methodology, operate to exclude women from science. It incorporates Schiebinger's (1987, p. 328) discussion of "gender distortions in science", and Rosser's (1989, pp. 8-10) two categories of "feminine science" and "feminist theory of science". It also incorporates Sandra Harding's (1986, pp. 23-4) discussion of whether the design and interpretation of research can be value-neutral, whether gender politics shapes the cognitive form and content of scientific theories, and whether beliefs about "what we honor as (scientific) knowledge" can be understood satisfactorily through feminist epistemologies. Although a number of different approaches have been taken in this category of work, that of Keller (1985) was a particularly fruitful source for the development, in this study, of a theoretical definition of gender-inclusive science.

KELLER: THE RECLAMATION OF SCIENCE

In some of her many "reflections on gender and science", Keller (1978, 1982, 1983, 1985, 1989) sought to explore the conjunction between science and masculinity and the disjunction between science and femininity. In an elaborate historical, psychoanalytical and philosophical analysis, she traced systematically the origins of androcentrism in science back to the very beginnings of Western knowledge. She presented, in her historical analysis, three periods as critical in the evolution of contemporary scientific thought and practice. These are Platonic thought, Baconian science and the "new" scientific thought prevailing around the time of the founding of the Royal Society. She argued that the model of gender relations and the culturally bound definitions of valuable knowledge prevailing during each of these periods ensured the exclusion of females from the evolving definition of science.

In Keller's view, Plato's conception of knowledge was influenced by the high value which Ancient Greek cultures placed on homoerotic love. She saw the contemporary distinction between pure and applied science as reflecting Plato's separation of the logical and the physical, and the hierarchy of laws underpinning modern physics as reflecting the upward looking of Plato's lovers in their search for supreme knowledge.

In her discussion of Baconian science, she demonstrated two dimensions of the exclusion of women. The first was the well known Baconian vision of science as leading to "sovereignty, dominion and mastery of man over nature" (1985, p. 34), the view that the relationship between human beings and nature is basically similar to an unequal, male-dominated, heterosexual union. Second, however, Keller posited that Bacon portrayed the learner of science as becoming empowered or "virilised" by a gift from the father, a perspective which clearly

emphasised denial of the maternal and the female in the definition of worthwhile knowledge and the way it is acquired.

Keller developed this theme further in her essay entitled (perhaps somewhat tongue-in-cheek) "Spirit and Reason at the Birth of Modern Science", an essay in which she traversed a great deal of territory, focusing on the intellectual debates which immediately preceded the founding of the Royal Society. Keller argued for the strong influence of the then current metaphors of gender on the formation of the particular set of values which underpin modern science. She demonstrated the misogynous perspectives underlying the rejection of what might be seen as other forms of science, such as alchemy and witchcraft. Above all, and resonating to some extent with a point made also by Brian Easlea (1986), Keller argued that, partly because of the cultural climate in which it evolved, the ideology of modern science gave men "a new basis for masculine self-esteem and male prowess" (1985, p. 64). She saw science as both responding to and providing crucial support for the polarisation of gender required by industrial capitalism. She commented that:

(i)n sympathy with, and even in response to, the growing divisions between male and female, public and private, work and home, modern science opted for an even greater polarization of mind and nature, reason and feeling, objective and subjective; in parallel with the gradual desexualization of women, it offered a deanimated, desanctified, and increasingly mechanized conception of nature.

(Keller, 1985, p. 63)

In the third, psychoanalytical section of her analysis, Keller, like Chodorow (1978), employed object relations theory to argue the association between objectivity and masculinity. Assuming a classical two-parent family with the mother in the primary nurturant role (an

assumption which could be rather less valid in 1994 than it was in 1978 which was the date of this section of Keller's work), Keller developed the argument that a child's early task of distinguishing self from other is perhaps the child's first exercise in attempting to distinguish between subjective and objective. She suggested that this experience could be stronger for a boy than for a girl, because of the boy's need to separate self-as-male from other (i.e. mother)-as-female. She saw this process as producing girls with a sense of self as connected to the world, and boys with a sense of self as separate from the world.

Keller thus anchored the association between objectivity and masculinity firmly in early childhood experiences. She forged the links between science and masculinity by highlighting this connection between masculinity and objectivity, and the consequent self-selection of scientists as people who gain emotional satisfaction from their belief that they are "objective", neutral and able to stand back, as it were, from their subjects.

Keller also explored the relationships amongst objectivity, power and domination. She challenged the familiar, relatively static, unilateral definitions of autonomy and objectivity, and put forward a model of both of these concepts which was dynamic and interactive, taking account of rather than neglecting a human being's connection to other human beings. The implications of her model for science are far-reaching. What emerges is a picture of science premised not on the desire to dominate, to master and to exercise power over nature, but on interaction with and internalisation of the object of enquiry. Keller noted, too, that such a picture, while not entirely legitimated by the rhetoric of science, is not totally foreign to the practice of science. Her reference to Goodfield's account of Anna Brito's research on tumors provides an excellent example of such an approach: "If you really want to understand a tumor, you've got to be a tumor" (Goodfield, 1981, p. 213, quoted by Keller, 1985,

p. 125). Her detailed and sensitive documentation of Barbara McClintock's approach to research, based on "a feeling for the organism" (Keller, 1983) provides an even better example.

In her work on McClintock, Keller presented an account of the practice of "different" science, and of the contribution to scientific knowledge made by this kind of practice. She touched eloquently on the dilemma, even identity crisis, which confronts women endeavouring to practise science within the currently dominant paradigm. Further, she raised the question of the cost to a woman, in personal identity terms, of trying to "share masculine pleasure in mastering a nature cast in the image of woman as passive, inert and blind" (1985, p. 174). She demonstrated how McClintock's solution (because she wanted to be a scientist, not because she was a woman) lay essentially in her interactive, non-hierarchical definition of the relationship between subject and object.

Keller also expanded on the scientific/philosophical aspects of her argument, using other cameos drawn from the annals of scientific research, in particular from her own experience as a practising scientist and philosopher of science. Through these examples, she explored the possibilities for paradigmatic change within science, with special emphasis on the impetus for any such changes which do appear to have taken place. One cameo concerned competing schools of thought within research on quantum mechanics theory, and the researchers' unwillingness to relinquish their belief that nature is objectifiable and knowable in some absolute way, or to deal adequately with challenges to this belief. Another cameo concerned her own experience as a mathematical biologist working on the slime mould. In this case, she demonstrated the prevalence of "master cell" or "pacemaker" explanations for the phenomenon of aggregation in the slime mould,

explanations which emphasise the concept of control over nature, rather than harmony with and within nature. She noted that her own published research arguing against the existence of a pacemaker cell had little impact on the dominant view. She suggested that this was because "master cell" theories tend to fit well with most scientists' views of the way nature should be represented, whereas her own alternative view did not map so well on to those of other scientists.

Four points of major importance to the study reported in this thesis emerge from Keller's analysis. The first throws new light, from a feminist perspective, on some of Young's statements about the social definition of science. In Keller's terms, gender ideology is manifested in the selection, by scientists, of what counts as science, and the recognition, by both scientists and non-scientists, of who counts as a scientist. The second and third points concern the limits and possibilities of change to the dominant paradigm of science. As Keller saw it, despite the overall imperviousness of science, change does take place, even if always in the face of what she called, in terms reminiscent of Kuhn (1970) "a web of internal resistance" (1985, p. 136). Further, she emphasised that if a changed or different science is to be accepted, it must emerge from within science by growth and not by discontinuity. The fourth point concerns the nature of this changed or different science. Keller saw it as based on the transcendence of the bias that she had identified in science, and the reclamation of science as a human instead of a masculine activity. Pluralism and eclecticism were fundamental to her vision of a scientific paradigm which "allows for the productive survival of diverse conceptions of mind and nature, and of correspondingly diverse strategies" (1985, p. 178).

OTHER FEMINIST RESEARCHERS: ADDING TO KELLER'S PICTURE

Although Keller's work is an important source of ideas for generating a theoretical perspective on gender-inclusive science, the purpose of this chapter could not be accomplished successfully, or with any validity, without reference to the work of other feminists in this area. In this respect, the work of Sandra Harding (1986, 1987, 1989, 1993), on whether or not there is a distinctive feminist method of scientific enquiry, has been discussed already in Chapter 3. Harding's perspective, while different from Keller's in that it is derived from experience in the social sciences rather than the natural sciences, is clearly congruent with Keller's in terms of its argument for pluralism and diversity. Other feminist scholars, as shown in this chapter, also have some points of difference with Keller, but their basic premise, in terms of the current masculinist, exclusive definition of science, remains the same.

The work of many of these scholars has been informed by the research of Gilligan (1982) who suggested that women speak "in a different voice" from men (and thus from the discourse of science) and by the research of Belenky, Clinchy, Goldberger and Tarule (1986) who posited that there are "women's ways of knowing" which are quite distinct from those of men. However, while there appears to be agreement amongst all of these scholars that there are "gendered" ways of relating to knowledge, there are markedly different interpretations regarding whether this is a phenomenon or a problem. As shown in the next sections, those who see it as a problem tend to place it in the context of rival paradigms and of irresolvable conflict and competition, a position which would not appear to augur well for effective social or educational change. Those like Keller, however, who accept it as a phenomenon, are more likely to recommend the acknowledgement and

constructive accommodation of this diversity, and the ultimate enrichment of science through diversity, a position which seems likely to hold much more promise for effective social and educational change.

Gynocentric Science - A Competing Paradigm?

Keller's solution to the androcentrism of science, as explained above, was to reconceptualise science so that it accommodates alternative ways of viewing and studying the natural world. Of the feminists who are not in agreement with this solution, some, such as Ginzberg (1989) have developed the Kuhnian principle of competing paradigms, in making contrasts between traditional androcentric science and what they call "gynocentric" science. Ginzberg (1989) picked up the Kuhnian proposition that "the proponents of competing paradigms practice their trades in different worlds" (Kuhn, 1970, p. 150). Like Keller, Ginzberg argued that gynocentric science (e.g. midwifery) has always existed alongside androcentric science (e.g. obstetrics). She argued also that, again like Kuhn's competing paradigms, these two ways of practising the science and craft of childbirth "disagree not only about the list of problems to be resolved, but also about the theories, methodologies, and criteria for success that will be used to assess the results achieved" (Ginzberg, 1989, p. 79).

In a further analogy to Kuhn's description of the resistance with which the dominant paradigm meets a competing paradigm, Ginzberg argued also that gynocentric science, at best, has been overlooked because it was defined as everyday women's work and, at worst, has been suppressed and discredited, sometimes violently, because of alleged associations with superstition or even evil. Overall, Ginzberg remained ambivalent, however. On the one hand she saw a more gynocentric definition of science as one way to make the world "better for everybody"

(p. 82) but on the other she was resistant to any association at all with the "baggage" of traditional science.

Challenging the Dominant Paradigm: Can Others "do" Science?

Much of the feminist critique of science has dwelt on the exclusive, self-perpetuating, self-reflexive nature of the group who are acknowledged as scientists, and the predominantly white, male, upper-middle class characteristics of this group. Hubbard (1989, p. 120) is amongst those who have pointed out that wider public accountability is not built into the current system of science knowledge-making. She argued that "other kinds of people" have a role in the making of science. She suggested that the inclusion of women in science needs to take place not by making women's domestic work more "scientific" in the traditional sense, but by "acknowledging the scientific value of ...the facts and knowledge that women have accumulated and passed on in our homes and volunteer organisations" (p. 128). She argued also that women's major contribution to science is as political beings who can expose the political content of science and its political role. Her vision was of a socially responsible science, involving a much wider range of people than at present in the setting of the agendas and the identification and answering of relevant questions – a science *by* the people, rather than a science *for* the people.

Can there be a Feminist Science?

Another question explored by others besides Keller concerned whether or not there can be a "feminist science". In attempting to answer this question, Longino (1989), like Keller, saw the categories of "feminine" and "science" as socially constructed. She emphasised also, like many others, that to define a single feminist anything is not valid,

because gender is experienced differently by different groups and individuals, according to the way it interacts with other variables such as class, race and ethnicity. On both of these grounds, Longino argued, like Sandra Harding (1987), against the idea of a feminist science. She suggested, however, that the focus should be shifted from the construction of a feminist science to the process of doing science as a feminist. In this sense, Longino saw feminist scientific practice as "highly interactionist, highly complex" (1989, p. 55). She noted with concern that such a model of scientific practice is not the preferred one, and that, without changes to the current social, political and economic climates, and the current views of legitimate scientific research, there is only a limited future for this model.

Irigaray (1985, cited in Grosz and de Lepervanche, 1988) also has contrasted a possible feminist science with science as conceptualised currently, focusing on a set of presuppositions which she saw as separating the scientific from the non-scientific. These presuppositions include

- the presumption of a reality distinct from the knower
- the imposition of models and grids, not as tools, but as reality itself
- a privileging of the visible, to the virtual exclusion of inputs from other senses
- an assumption of the neutrality of technological equipment
- an assumption that repeatability (irrespective of the sameness of two experimenters) is the fundamental criterion for objectivity
- the equation of the ability to manipulate and control with progress and knowledge.

While arguably, Irigaray's presuppositions are characteristic of what many would call "bad" scientific practice, her analysis nevertheless is useful in identifying the features assumed to be prerequisite for

scientific rigour. She argued that three minimal conditions need to be met – first, the substitution of symbols for proper nouns, second, the focus on the quantitative rather than the qualitative and, third, the use of formalised language – all of which act to seal science from the everyday world and to make it an activity exclusive to those who prefer to deal in symbols, numbers and formalised language.

The Language of Science

In the context of language, there has been considerable debate as to whether or not the language of science allows for the emergence of alternative ways of doing science. In this context, Irigaray (1989) argued convincingly that "the language of science, like language in general, is neither asexual nor neutral" (p. 58). She pointed out that the subjective *I*, *you* and *we* do not appear in the traditional language of science, and that, overall, the discourse of science is much more comfortable with relationships of negation, conjunction and disjunction than it is with reciprocity, exchange, permeability or fluidity. Keller's example of the "master cell" has demonstrated the prevalence of concepts of power and control in the metaphors of science. Irigaray went further, showing how the very discourse of traditional science imposes limits on what is accepted as "science".

This perspective is also of interest in the context of the research of Bernstein (1971a) reviewed in Chapter 2 and the writings of some feminists (e.g. Gilligan, 1982; Spender, 1980) on male and female discourses. In his early work on language codes, Bernstein (1971b) described the "restricted code" (associated with working class families) as functional, ritualistic, standardised, directional and authoritarian. These characteristics would, in Irigaray's terms, be associated with traditional science and in Gilligan's and Spender's terms [as noted by Byrne (1988)],

be associated with maleness. By contrast, Bernstein's "elaborated code" linked by him to families of higher social class, was described by him as involving more conditionals and subjunctives, more negotiation and probability, and able to be modified in the light of an audience's special attributes and contexts – characteristics which would link it linguistically, in Irigaray's terms, to a non-traditional version of science, and in Gilligan's and Spender's terms, to femaleness.

Are Scientists Made?

The object relations perspective on human development which underpins much of Keller's theorising is supported strongly by several other feminists. From a theoretical perspective, Weinreich-Haste (1986) used it as a fundamental plank of her argument that a "new form of rationality" is evolving which allows for "differences in how scientific activity is conceived and how the products of science and technology are evaluated" (p. 121). From a science education point of view, Jan Harding (J. Harding, 1986; Harding & Sutoris, 1984) and John Head (1980, 1985) also based their arguments with respect to girls' and boys' choice of science on object relations theory. They drew on empirical research (e.g. Roe, 1952), which claimed that practising scientists tend to be emotionally reticent and minimally oriented to people, apparently because of isolation due to trauma or loss in early childhood. They highlighted the implications of these characteristics (in other words these kinds of people and this kind of image of science) for science curricula and the choice of these curricula by boys and girls. They argued that the presentation of science "as a system of generalizations and immutable laws, divorced from the problems of the world" (J. Harding, 1986, p. 163) reflects the documented personality characteristics of practising scientists. Further, in support of their argument, they demonstrated empirically that science

appeals to boys who tend to be emotionally immature and who see it as a subject separate from human relationships, but that the girls who choose science tend to be of above average maturity and tend to have made their choice in the hope that they will be able to apply their scientific learning to improve the quality of life. It is interesting to note that essentially, the Harding/Head analyses present a theoretical perspective on the practical issues concerning the "packaging" of school science curricula which were discussed in Chapter 4.

Is Neutrality Enough?

To some, Keller's argument for more diversity in science can appear to be an argument for science to be "gender neutral". As argued emphatically by Martin (1982, 1985), this is not the case. Martin discussed a number of traditions in women's education. She pointed out the "sex neutral" tradition is derived from Plato and was espoused by most curriculum theorists until the beginning of the 1970s. This tradition maintains that curriculum offerings should not be differentiated according to sex, an argument which on its own could be acceptable. However, as Martin (1982) pointed out, this presumption that sex was irrelevant to learning was operationalised within a concept of learning as detached from everyday life, in the tradition of "the Oxford tutor, the graduate seminar" (p. 144). It ignored what Martin called the "reproductive" aspects of life (domestic and interpersonal life) and it focused on the "productive" aspects of public life, aspects which culturally were denied to women. Thus, as Martin argued, it was not sensitive to the reality that "men and women in the past and the present do not have identical experiences and are not seen as identical by the culture. ...Treating them as if they were the same is not to treat them equally" (p. 107).

THE PLACE OF DUALISMS

A Cautionary Note

This chapter returns now to one of the consequences of the kind of analysis carried out by Keller, a consequence associated with the issue of competing or compatible paradigms which was discussed earlier. This consequence, which has been identified with some concern by several feminists (e.g. Bleier, 1984; Glennon, 1979; MacCormack & Strathern, 1980; Weinreich-Haste, 1986) is that it can lead to a set of dichotomies or dualisms. Feminised science, contrasted to a picture of traditional masculinist science in terms of such dualisms, can be seen as science premised on

- an holistic rather than an atomistic approach
- order rather than law
- mutual respect and interaction rather than domination
- a non-hierarchical continuum of difference rather than a dichotomy and polarisation
- involvement rather than detachment
- understanding rather than predicting
- empowerment through understanding rather than power to manipulate
- broadly defined rather than highly specialised scientific knowledge
- scientific knowledge contextualised in history and in contemporary society, rather than ahistorical and decontextualised scientific knowledge.

Sets of dualisms such as these are ubiquitous in Western philosophical traditions. As Schiebinger has pointed out:

The basic categories of modern thought have taken shape as a series of dualities: reason has been opposed to feeling, fact to values, culture to nature, science to belief, the public to the private. One set of qualities – reason, fact, object – came to represent constituents of rational discourse and scientific knowledge. The other set of qualities – feeling, value, subject – have been defined as unpredictable and irrational. When the dualism of masculinity and femininity was mapped onto these categories, masculinity became synonymous with reason and objectivity – qualities associated with participation in public spheres of government, commerce, science and scholarship. Femininity became synonymous with feeling and subjectivity – qualities associated with the private sphere of hearth and home.

(Schiebinger, 1987, p. 331)

Many feminists see such dualisms as dangerous. First, they take the view that the mapping of identifiable categories of human beings on to any set of dichotomies such as these denies the variation within those categories, denies the holistic nature of humanity and carries with it all the risks known to be associated with stereotyping. Second, as noted by Collins (1993), they see this as an example not only of the way that language works through oppositional concepts such as those identified above by Schiebinger, but also of the way the value relation built into each binary pair of constructs tends to valorise the masculine and to define the feminine simply in terms of what is not masculine. Third, they point out that, although such dualisms represent one kind of tool for describing the world, they are not used as such. The dualisms are posed not as hypotheses to be investigated, or as ends of a continuum, but as self-evident truths with predictive and definitional significance. As Bleier has noted (1984, p. 197), "we tend to mistake our cognitive

techniques to comprehend the universe for the universe itself" and, as emphasised by Lemke (1994), the disjunction read into dualisms ensures that the two poles of the duality are mutually exclusive.

In educational terms, clearly it is highly problematic if these dualisms are enforced as reality itself, rather than only as representative of reality. If "science" and "not science" are defined strictly in terms of this set of dualisms, and if the set includes "masculinity" and "femininity", then inevitably young people are forced to risk an identity crisis at the choice point in their schooling (i.e. the point when they make their choice of future study or occupation). In Keller's words, "any scientist who is not a man walks a path bounded on one side by inauthenticity and on the other by subversion" (1985, p. 174). Arguably, if these dualisms are embedded unquestioningly in school science, the choice point at which females and males choose whether or not to continue with science, and if so, which science, will continue to be a critical event in the science education of all students.

Dualisms as Complementary rather than Oppositional: A Theoretical Model of Gender-inclusive Science

The position of this thesis is that these dualisms have served a valuable intellectual purpose in the past, and, as will be seen from the theoretical framework developed in this thesis, can continue to do so in the future. They have helped feminist scholars to expose some of the problems inherent in a narrowly defined science. Further, most feminists are aware of the trap posed by dualistic modes of viewing the world. Longino (1989, p. 47) noted the fallacy inherent in rejecting one approach to science as incorrect and embracing another as the way to a truer understanding of the natural world, or, in her terms, trading "one absolutism for another". Like Sandra Harding (1986) and Lorraine Code

(1993), she pointed out that women's backgrounds and experiences are too diverse to justify the generation of a single cognitive framework for either feminine science or feminist science. Similarly Alcoff (1987) argued that simply removing the masculine will not "purify" science. And Keller herself, despite the many contrasts she set up, recognised nevertheless the trap in substituting "feminine" science for "masculine" science or, as she put it, substituting "one form of parochiality for another" (1985, p. 178).

As indicated earlier, Keller's vision was pluralistic and eclectic, based on a transcendence of the bias she identified in science, and on the reclamation of science as a human, instead of a masculine activity. Weinreich-Haste (1986) asked the question: "Does rationality overcome a dualistic world view?" Keller's answer would appear to be a resounding "Yes!", as would that of Weinreich-Haste herself, who, in alignment with Keller's view of reformed science, proposed that her new form of rationality is "*in complement to the traditional form*" (p. 121, italics added) not in competition with it, or replacing it.

In accepting this pluralism, the picture of science presented in oppositional terms earlier in this chapter becomes a picture of a discipline premised not on an holistic rather than an atomistic approach, but on

- an holistic as well as an atomistic approach
- order as well as law
- mutual respect and interaction as well as domination
- a non-hierarchical continuum of difference as well as a dichotomy and polarisation
- involvement as well as detachment
- understanding as well as predicting
- empowerment through understanding as well as power to manipulate

- broadly defined as well as highly specialised scientific knowledge
- scientific knowledge contextualised in history and in contemporary society, as well as ahistorical and decontextualised scientific knowledge.

In accepting this version, however, the caution of Weinreich-Haste must be heeded: because of the deeply rooted dualisms in Western culture, the emerging, more holistic, less control-oriented conception of rationality "has been mapped onto the gender dichotomy" (1986, p. 129) or, in the terms of this thesis, it has become "gender-coded".

IMPLICATIONS FOR A GENDER-INCLUSIVE SCIENCE CURRICULUM

The Problem for School Science

Although the work of Keller and most other feminists does not deal directly with school science, it has considerable application to this area. In this sense, some postmodernist analyses (e.g. Collins, 1993) provide important background to the place of science in the school curriculum. These analyses place science, as traditionally taught, as one of the more recently emergent lynch-pins of the kinds of school curricula which have dominated the English-speaking world during most of the twentieth century. They argue that these curricula have been, and for the most part still are, based on modernist assumptions about the world, assumptions which became hegemonic during the nineteenth century. As Collins (1993) pointed out, "modernism was about empirical evidence and the rule of reason" (p. 5), and, in this context, one of the strands which is historically traceable concerns "the rise in the prestige of physical science, the kind of totally predictable science which can be used

to control, to the pinnacle of preeminence" (p. 5). Collins emphasised that, even in the 1990s, at least in Australia, the school curriculum remains dominated by "technocratic, modernist priorities: mathematics, physics, chemistry and more recently economics (*taught as positivist truth*)" (p. 10, italics added).

The positivist truth alluded to by Collins essentially is part of what Keller (1985, p. 125) called the "dominant rhetoric" of science. As demonstrated by Malcolm's (1989) description of school science cited in Chapter 4, the problem for school science appears to be that it has tended in the past to replicate this dominant rhetoric, replicate it much more faithfully than the practice of science by scientists. Shapin and Barnes' (1976) elegant analysis of documents associated with the science curriculum offered in the 19th century British Mechanic Institutes demonstrated clearly the dominance, in science education at that time, of a simplistic view of science focused on control over nature. Similarly, as part of this present study, scrutiny of the 1986–1991 Syllabus Manuals of the Secondary Education Authority in Western Australia, demonstrated that school science knowledge, in the late 20th century, represents a distillation of what is seen as the essence of the discipline of science, a representation which is, in many cases, an outdated oversimplification.

In attempting to characterise science as an area of study, school curricula appear to have emphasised the things which are alleged to make science different from other areas of human activity rather than what science might have in common with other human activity. Control, objectivity, reasoned argument and value-free "truths" of science are presented in opposition to chaos, subjectivity, irrationality and value-embedded "not science". The hierarchical orderings and fixed approaches to scientific enquiry which are part of many traditional science curricula reinforce a simple, competitive, individualistic, linear

view of science, rather than one which is complex, egalitarian and interactive. Science is presented as "the tale of better control of the natural environment...the story of triumph of the rational, of the rule of the head" (Collins, 1993a, p. 4). As Birke (1986a) commented, "impersonal, reductionist kind of science...is still the backbone of school and college biology" (p. 195). She pointed out that, "if girls (and some boys) are opting out of science at school because they want to see nature in terms of relationships and connectedness, then we have to change the image of science that is conveyed in schools" (1986a, p. 196). First, however, we need to clarify the ways in which that image needs to be changed.

Change to What? – The Reconstructed Image of School Science

The theorising of postmodernist feminists discussed in this chapter has clear implications for the reconstruction of school science curricula to make them more gender-inclusive. As demonstrated from the empirical research discussed in Chapter 4, Keller's arguments for science to be reclaimed as a fully human rather than a masculine activity have just as much validity in relation to school science as they do in relation to the practice of science by scientists. Thus, her vision of an eclectic, pluralistic science, which accommodates diverse ways of thinking about and doing science, needs to be fundamental to any reconstructed image of school science. In terms of curriculum theory, such a transformation is consistent with the culmination of the developmental, sequential model of curriculum transformation proposed by Schuster and Van Dyne (1984) for the liberal arts. The sixth and final stage of Schuster and Van Dyne's model portrayed, like the curriculum advocated here for science, a transformed, balanced

curriculum and an inclusive vision, based on diversity of human experience, not sameness and generalisation.

In operational terms, it is insufficient for diversity simply to be facilitated or provided for in this reconstructed school science curriculum, however. Diversity needs to be embedded in the curriculum, the pedagogy and the assessment – in other words, in all three of the message systems in Bernstein's model (as explained in Chapter 2). Clearly also, such a curriculum involves a major shift from the collection code to the integrated code. Both the classification and the framing of this reconstructed school science are considerably weaker than those of traditional, high status science curricula.

First, with respect to classification, the reconstructed curriculum would need to include the "her-story" of science and the work of "the lost women of science" alluded to earlier in this chapter. It would need to expand the boundaries of "science" and the definition of legitimate scientific knowledge to include science which takes place in contexts of domesticity or nurturance. It would need to project an holistic, non-hierarchical view of science – a view quite at odds with the division of science into a hierarchy of separate subjects such as occurs currently in most upper secondary school science curriculum structures. It would need to include, as an essential part of scientific knowledge, a discussion of how that knowledge has evolved, and how it has been "used and abused". Overall, in doing all of this, it would need to ensure that androcentric and gynocentric science are not presented as competing paradigms, with the former valued more highly than the latter, but as a single global entity, where diversity is part of the integrity of the discipline.

Second, with respect to framing, the pedagogy of this reconstructed curriculum would need to allow for discussion of the extent to which

science is value neutral and objective, and to provide opportunities for personal involvement of students with science, in the manner of Keller's description of Barbara McClintock. In addition, the pedagogy would need to allow also for different entry characteristics of students, different ways of viewing the world, "ways of knowing" other than men's ways, "different voices" from men's voices and the doing of science by people other than men. Further, and at the very least in the interests of validity, the assessment procedures – an important part of the framing – would need to match the pedagogy faithfully and to reflect the diversity embedded in the teaching strategies.

Clearly, this kind of science curriculum does not conform to the set of preconditions presented earlier in this chapter as fundamental to scientific rigour, conditions associated with the detached, symbolic, numerical and formalised representation of reality. This raises questions regarding whether such a changed science can be accepted as real and rigorous science and whether, indeed, rigour itself is an ideology. These questions are addressed in the final chapter of this thesis, following the report of the theory-testing phase of this study.

CONCLUSION: HYPOTHESISING THE GENDER CODE OF SCHOOL SCIENCE

The picture of gender-inclusive science which emerged from the theoretical analyses reported in this chapter was very similar to that which emerged from empirical evidence of the kind of curriculum which, as demonstrated in Chapter 4, appears to be associated with increased participation and achievement by females. As indicated in both chapters, this kind of curriculum has clear links to Bernstein's integrated code curriculum. However, the extent to which it is perceived also as

low status knowledge (in Young's terms) and as not legitimate because of its informal assessment procedures (in Broadfoot's terms), remained an open question at this point in the study.

Despite this open question, it was possible, at this stage of the study, to develop the hypothesis that *school science is gender coded in ways which associate maleness with Bernstein's collection code, Young's high status knowledge and high legitimacy because of Broadfoot's formal assessment procedures; and conversely, which associate femaleness with Bernstein's integrated code, Young's low status knowledge and low legitimacy because of Broadfoot's informal assessment procedures.* Essentially, the research reported in Chapters 6, 7 and 8 of this thesis constituted a testing of this hypothesis.

Chapter 6

GENDER AND THE CONCEPT OF SCIENCE-FOR-ALL: THE CASE OF *PHYSICAL SCIENCE* IN WESTERN AUSTRALIA

INTRODUCTION

Purpose of the Chapter

To this point, the study reported in this thesis has developed a theoretical perspective on the stratification of knowledge, a perspective from which high status knowledge is seen as presented in a curriculum characterised by a collection code, that is, strongly classified and framed, and legitimated by formal, external assessment. Low status knowledge, by contrast, is seen as associated with an integrated code, weakly classified and framed curriculum, with a variety of forms of assessment to provide students with multiple opportunities to demonstrate their knowledge.

More specifically, the study developed a hypothesis with respect to a gender code of school science, namely, that *school science is gender coded in ways which associate maleness with Bernstein's collection code, Young's high status knowledge and high legitimacy because of Broadfoot's formal assessment procedures; and femaleness with Bernstein's integrated code, Young's low status knowledge and low legitimacy because of Broadfoot's informal assessment procedures.* The gendered associations with Bernstein's codes, and to a certain extent with Broadfoot's modes of assessment, were supported by empirical evidence (presented in Chapter 4) and feminist theory (presented in Chapter 5).

This chapter reports the exploration of the extent to which perceptions of knowledge status (in Young's terms) are also gendered. It focuses on a gap revealed by the review of empirical research in Chapter 4, namely, the gender effect of structural, policy-level changes to an individual science subject at the senior secondary level.

Much of the previous discussion has focused on the hierarchy of school subjects produced as a consequence of the knowledge stratification referred to at the outset of this chapter. It also has drawn attention to the generally favourable location of science in this hierarchy, as part of what Collins (1989) termed the "positivist hegemony". However, as Young (1974, 1975, 1976) pointed out, in addition to analysing judgements involving *science within a hierarchy* of school subjects, it is equally illuminating to analyse judgments about *hierarchies within school science* knowledge itself. He suggested that we might well ask what it is "about the way we conceive of science, and the way school science is experienced, that restricts a major human activity to a minority pursuit" (1974, p. 58). Historically, this kind of question has been and, indeed, remains fundamental to attempts to develop and implement curricula aimed at science-for-all. Further, as indicated in Chapter 2, similar questions are central to this thesis, in the context of the image of science as an essentially masculine pursuit. Previous analyses, however, have not made clear the link between school science curricula aimed at science-for-all, and school science curricula aimed at making science more gender-inclusive. To achieve the purpose of this thesis, that is, to advance understanding of the relationship between gender and science, the factors affecting implementation of both of these kinds of curricula, and the links between the two kinds of curricula, need to be explored.

Outline of the Chapter

Essentially, this chapter presents a test of the theory of the gender code of school science through a socio-historical analysis of the introduction of *Physical Science*, a science-for-all, integrated code subject, into the Western Australian upper secondary school science curriculum. The chapter begins with a critique of some of the system-level attempts, elsewhere in the world, to translate the concept of science-for-all into a viable curriculum for senior secondary school students. It provides a considerable amount of background regarding these attempts, discussing both theoretical and practical issues. In particular, it notes that, although analyses of these implementations have illuminated the issue of the relative status of science subjects, none of the analyses has made mention of gender-related issues. The chapter then focuses specifically on *Physical Science* in Western Australia. It explores status issues, in relation to Young's theory, by building on data from the Physical Science Evaluation Project (Andrich & Parker, 1980; Boud, Dynan, Parker & Ryan, 1979; Dynan, Parker & Ryan, 1979) and it explores gender issues through a new reanalysis of data from the same project.

SCIENCE-FOR-ALL IN THE SENIOR SECONDARY SCHOOL CURRICULUM

The Background

As Fensham (1985) remarked in his major review essay on the topic, science-for-all is "a vision splendid" (p. 435). Indeed, during the 19th and 20th century, the vision of science-for-all has surfaced a number of times in various forms. For example, there was Dawes' "science of common things" in the 1840s, Hogben's "science for the millions" in the 1930s and Layton's "science for the people" in the 1970s. The

implementation of the concept of science-for-all in the upper secondary school curriculum, however, has been essentially an issue belonging to years since the mid-1970s.

The collection code model of curriculum dominating school science education in most parts of the world during the 1960's and 1970's has been outlined in Chapter 5. As described by Fensham (1985, p. 418), it involved, amongst other things

- the rote recall of a large number of facts, concepts and algorithms that are not obviously socially useful;
- concepts that have been defined at high levels of generality amongst scientists without their levels of abstraction being adequately acknowledged in the school context, and hence without adequate indication of their limitations in real situations;
- an essentially abstract system of scientific knowledge
- practical activity associated with the belief that this activity enhances conceptual learning rather than being a source for the learning of essential skills;
- content giving a high priority, even in biology, to the quantitative.

In Australia, and to a large extent also in the UK, this model provided also a strong reminder of the Latin origins of the word *curriculum*. The senior secondary school curriculum was indeed a racetrack. All students were expected to run the same course and jump the same fixed hurdle, in the form of an external examination at the end of Year 12. The major purpose of the curriculum was to prepare students for studies of science in higher education. The major purpose of assessment was to rank students for the purpose of selection for higher education. The educational value of assessment was minimal, except

perhaps as a force for motivating students to learn what was going to be examined, which may or may not have borne a close relationship to what was supposed to have been or had been taught. Moreover, in this system, as indicated by Parker and Rennie (1992), the limited nature of the assessment tasks administered, together with students' predilection to learn only what was being examined, combined to form an impediment both to equity and to real scholarship.

During the 1970s, this model was challenged from many different directions. In Australia, social change and educational research played their part in the challenge, but perhaps the most compelling stimulus for change came from demography. As alluded to briefly in Chapter 1, the retention of students in schools beyond the minimum compulsory Year 10 level began to increase dramatically in the 1970s. Schools were confronted to an increasing extent with a larger and more diverse group of students in Years 11 and 12. They began to realise that curriculum and assessment procedures which had been designed for the 20 percent of the cohort destined for tertiary level study were patently inappropriate for the close on 60 percent undertaking post-compulsory schooling by the mid-1970s.

In addition, assumptions about what students learned in Years 11 and 12 and about models of learning previously considered appropriate to those years began to be exposed as quite invalid. In many parts of the world, concerns were expressed about students' level of understanding of scientific concepts, particularly in an environment in which universal scientific literacy was being defined as a desirable outcome of schooling. In former times, when science had been considered the domain of an elite, mostly male, group, those who either could not or would not engage in science education usually had been designated as deficient in some way – intellectually, genetically or culturally. Strategies to involve

more students in science had focused on changing the intellectual and cultural capital of these "deficient" learners to bring it more into line with that of the elite already attracted to science.

By the beginning of the 1980's, however, such definitions, explanations and actions had been exposed as somewhat flawed. It was becoming clear that, for universal scientific literacy to become a reality, there was a need to resolve the paradox between, on the one hand, its implied universalistic view of science and, on the other hand, the tradition of science as "the property of specialist elites, whose bodies of knowledge were increasingly removed from the common knowledge of society at large" (Berger & Luckmann, 1967, p. 130). Young himself raised some of these concerns in the context of student failure to learn science. He pointed out that school science, as practised at least up until the 1970s, had produced three kinds of people:

(a) 'Pure scientists', whose relations with nature are at best those of abstracted understanding ... (b) the 'applied scientist' whose identity is fundamentally pragmatic ... (c) the identifiable failures of school science ... whose schooling teaches them that science is a specialized activity over which they neither have nor could have any control.

(Young, 1976, p. 59)

Young suggested that, if this problem was to be addressed, the science curriculum would require content and teaching strategies that are very different from the traditional curricula with their elitist view of science as an objectively available body of knowledge to be transmitted. Indeed, foreshadowing to some extent a constructivist approach, he saw the revised curriculum as requiring an approach which takes account of pupils' prior knowledge and definitions of reality. In this context, he made one of his rare references to the relationship between gender and

science, remarking (1974, p. 38) that the low proportion of girls in science was being represented as educational failure of girls due to some fixed attribute of females, rather than as an "extraordinarily severe example of sex typing" connected to attributes of science.

Also during the 1970s, especially in the UK and Australia, concerns were being raised about the decontextualised kind of science presented in the traditional science curricula, and the remarkable absence of the practical and the applied. These concerns were linked to students' reported disillusionment, dislike and boredom with school science and to students' increasing tendency to omit science from their upper secondary school programs of study. Some critics of the then current science curricula focused also on the alienating capacity of science, and the separation of science from everyday activities and everyday people, features which Young, like Layton (1973), saw as a legacy of the historical traditions from which science developed. As indicated earlier, traditionally, science was not part of general education. It was part of elite education, a "rigorous mental training", with "the learner slowly inducted into the ways of the scientist – a particular type of scientist – the 'pure' researcher" [Layton (1973) quoted by Young (1977, p. 257)]. Other forms of knowledge were defined as "not science".

In this context, which included also an upsurge of interest in environmental issues, there were moves, in some parts of the UK and Australia, to make policy decisions about the content and pedagogy of upper secondary school science reflect a broader range of influences. A considerable amount of action was focused on the absence, in school science curricula, of links between science, technology and society, and of discussion of moral or ethical dilemmas related to science. In addition, in some cases, what became known as the "concepts in contexts" approach was implemented. This represented a major shift to an

integrated code model of curriculum, with scientific concepts developed in real world contexts, and considerable emphasis on open-ended investigations of a problem or issue that related to the topic being studied.

The questioning, the shifts and the articulation of concerns reached a crescendo in the 1980s, years which also saw an increased demand for universal scientific and technological literacy. Government reports (e.g. Australian Science and Technology Council, 1987; Science Council of Canada, 1984) reiterated this demand, while academics and practitioners grappled with the dilemmas and problems inherent in attempts to provide a curriculum design which facilitated science-for-all. Fensham's (1985) description of the characteristics of a science-for-all curriculum points clearly to the generally integrated code nature of such a curriculum:

- (a) It should involve content that has immediate and obvious personal and social relevance to the learners.
- (b) Its learning objectives (practical skills and knowledge) should have criteria of achievement that most learners can realize at some level.
- (c) Its broad themes, topics or sections should constantly be visible to elucidate the component parts of the learning.
- (d) Its pedagogy should exploit the demonstration and practical modes that are inherent to much science and also to the cultural learning that occurs prior to and outside schooling.
- (e) The learning of practical and cognitive skills should flow naturally from the relevant and meaningful nature of the science topics rather than be themselves a primary focus of the learning.
- (f) Its assessment should recognize both the prior knowledge that the learners have of scientific phenomena and their subsequent achievements in all the various sorts of criteria that make up the curriculum.

(Fensham, 1985, p. 426)

The Response to Science-for-All Syllabuses

As early as 1974, Young clearly was concerned about science-for-all syllabuses, although his concerns went unrecognised outside of the group of academics with whom he worked. In developing his arguments, Young (1974, 1975, 1976) drew attention to the demise of the movement for the science of "common things" (Layton, 1973) and to Davie's much earlier study of the fate of the humanistic traditions of Scottish science (Davie, 1961). Young expressed concern about innovations in science teaching, such as Nuffield science in the UK, which were devised to include more real world science, and to attract more students to science. He argued that, despite their aims, these innovations, in practice, perpetuated oppositions between relevant knowledge (which came to be defined as non-academic) and the intellectually credible curriculum defined as essential for academic studies. He argued also that these innovations exacerbated schools' and school systems' practice of explaining lack of participation and success in science through reference to the characteristics of students, rather than the characteristics of the science knowledge offered.

In a related argument, Fensham (1985, p. 422) pointed out that, on the one hand, the education and selection of an elite group of scientists, and, on the other hand, the provision of science-for-all, are "competing and conflicting interests in schooling". He developed the concept of a "containment policy" in relation to this competition and conflict. Operationally he defined such a policy as limiting the provision of science-for-all to a specific level of schooling (e.g. Year 10), or alternatively as confining elite science education to a specific level (e.g. Years 11 and 12), and offering no effective science-for-all at this level. As is shown later in this thesis, until recently, a containment policy such as

this operated in Western Australia at Year 10 level. Science-for-all was "contained" effectively in the multidisciplinary science curriculum which operated at lower secondary level until 1987, and above that level, the biological science subjects tended to fill the place of a science-for-all curriculum – a somewhat anomalous situation, given that these subjects contained no physical science at all and thus only gave students access to, at best, half the scientific world.

The Implementation of Science-for-All at the Senior Secondary Level

Partly because of the operation of Fensham's containment policy, there have not been a large number of attempts to implement science-for-all at the senior secondary level. Further, even in relation to the attempts which have been made, documentation and analysis are quite limited. Given the importance of such attempts in the context of the theoretical and practical issues addressed in this thesis, two such attempts are discussed here. Both of these examples demonstrate clearly the association between low status knowledge [in Young's (1971b) terms of abstractness, individualism, unrelatedness and an emphasis of written work, as discussed in Chapter 2], perceived lack of rigour [in Irigaray's (1985) terms of symbols, quantification and formalised language, as discussed in Chapter 5] and an integrated code science curriculum (such as emerged from the Bernstein/Young/Broadfoot analysis in Chapter 2). The first example is the implementation of environmental education (offered as *Environmental Studies* and as *Environmental Science*) in the British GCE A level system, and the second is the implementation of *Physical Science* in the Victorian Higher School Certificate in Australia.

Environmental Education in the British GCE A levels

Gayford's (1986) analysis of the implementation of environmental education reflects some specific aspects of the general portrait of science-for-all curricula given above. Gayford pointed out that the rationale for the introduction of environmental education was supported strongly. Consistent with the increased interest in environmental issues identified earlier in this chapter, the support was articulated mainly in terms of human survival, and was linked to the UK's conservation and development program, a program which itself had been conceived as a response to the World Conservation Strategy. Thus, as reported by Gayford, the subject was characterised by relevance to the pupils' concerns, links to the world of work, a broadening effect on students' education, and an affective dimension not present in other science subjects – all factors which, in Bernstein's terms, anchored it firmly in the tradition of an integrated code curriculum.

Reviewing nearly two decades of implementation of environmental education, Gayford (1986) concluded that it had "had a somewhat uneven and disappointing existence" (p. 147). More specifically, he carried out an analysis based on a series of surveys covering a large proportion of centres which offered the subject for examination during the period 1981–1985. His analysis revealed seven likely reasons for this lack of enthusiasm and, although the analysis made little reference to the students involved in environmental studies, and no reference at all to gender issues, it is useful in the context of the theoretical framework developed in this thesis.

While recognising that it is difficult for any new subject to become established in the senior secondary academic curriculum, Gayford's seven reasons point to some generalisable factors which appear to be associated specifically with the implementation of an integrated code

science curriculum. First, there was confusion over the subject's nature and identity. As discussed also in detail by Goodson (1983), the origins of environmental studies lay with the established areas of biology, geography and rural studies, and there were tensions between it, as a new subject, and these established subject areas from which it was derived – "subject chauvinism" as Gayford called it. Second, Gayford found that the subject was perceived by teachers, parents, pupils and others to be a minority subject, of low status, a perception which appeared to be associated with its "integrated approach". Third, environmental studies tended to be taken up by the lower ability pupils in schools, while the more able pupils continued to study the traditional academic disciplines. Fourth, the affective component of the subject appeared to create a barrier to its implementation by specialist science subject teachers, who were accustomed to a more formal curriculum where cognitive areas were of prime concern because of examination pressures.

Fifth, there were a number of issues associated with university acceptance of the subject. The universities apparently were unwilling to give unequivocal support to an integrated subject, and professed to see it as not intellectually demanding and not relevant preparation for the discipline-centred studies in universities. They expressed concern over its loosely defined boundaries. Publicly, they took the position that A-levels in environmental studies would be regarded less highly than A-levels in physics, chemistry or biology.

Sixth, there was a set of factors related to teachers [also explored in depth by Goodson (1983)]. These concerned the lack of consensus about the objectives of the subject, the blurring of the boundaries because of the involvement of teachers from different subject areas, the limited potential for the teachers involved to form a cohesive professional group [one of Layton's (1972) preconditions for the establishment of a subject]

and the uncertainty in the minds of the teachers about its acceptance for tertiary studies. Finally, an additional impediment to the successful implementation of the subject was that there was a lack of teaching material, especially local and up-to-date materials, to support students and teachers.

As intimated above, the socio-historical analysis of Goodson (1983) supported many of Gayford's points. Goodson demonstrated also the broader point that, in the process of establishing a school subject, there tends to be a movement away from the utilitarian and pedagogic traditions towards academic traditions, and that, if a subject cannot demonstrate sufficient of the latter, it will be rejected as a legitimate inclusion in the school curriculum. Some of these kinds of demands and constraints were discussed also by Fensham (1988b) in the second of the two examples to be treated in detail here, namely, the example of *Physical Science* in the senior secondary curriculum in the Australian State of Victoria.

Physical Science in the Victorian senior secondary curriculum

In 1976, a new subject, with the title *Physical Science: Man and the Physical World*, was introduced into the Victorian senior secondary curriculum. (The title was changed in 1983 to *Physical Science, Society and Technology*, reflecting perhaps some developing sensitivity to gender issues.) The origins of *Physical Science* in Victoria reflected a complex of factors. Paramount amongst these was Collins' (1989) "positivist hegemony" – the established position of the collection code subjects *Physics* and *Chemistry* in the Victorian upper secondary curriculum, and the tendency of students who enrolled in these two science subjects to enrol also in two mathematics subjects, thus limiting considerably their opportunities to study subjects other than science and

mathematics. In this context, one of the original ideas in developing *Physical Science* was to give students more flexibility and breadth in their choices, by providing a single subject which covered both physics and chemistry. At the same time, the subject was designed also to include a science/ technology/society emphasis and, as documented by Fensham (1988b), it paid "overt attention to pure science, applied science and technology and the cultural impact of science" (p. 380).

At a practical level, two difficulties with the new subject were recognised and catered for in its developmental and early implementation phases. The first concerned the impediment identified by Gayford in relation to environmental education in the UK – the lack of readily accessible materials to support teachers and students. In the case of *Physical Science*, this problem was addressed through the provision of a specially prepared student text, teacher's guide and laboratory manual. The second problem concerned the difficulty of assessing this kind of science course solely through pen and paper examinations. This was addressed by the allocation of a significant proportion of the final mark in the subject to assessment of practical and project work and the provision, by the curriculum developers, of appropriate assessment tasks.

Despite these precautions, however, the existence of *Physical Science* in Victoria was characterised by many problems similar to those experienced in the implementation of environmental education in the UK, especially problems concerning the low status of the subject, low enrolments and negative reception by the tertiary sector. Although, as in the case of environmental education in the UK, details of the background or sex of the students who enrolled in the subject are not documented, what is documented is that there were relatively few of these students. Further, it is documented also that *Physical Science* suffered badly from

the negative attitudes of established physics and chemistry academics in at least one Victorian university (Fensham, 1988b). This negativism culminated in 1986, in a declaration by the University of Melbourne that *Physical Science* was no longer an approved subject for entrance to any faculty. The reasons given were that "the subject's form of assessment had an insufficient degree of externality to maintain the university's confidence, and the content of the subject was not worthy of the Year 12 standard" (Fensham, 1988b, p. 375). Again, as in the UK case of environmental education, the guardians of knowledge in the universities were exercising great power over the content and opportunities available in the upper secondary school curriculum. The integrated code subject *Physical Science*, a subject which treated seriously the social, political and economic aspects of the science/technology/society interaction, and the assessment of practical work and projects, was perceived as a threat to the high status, collection code subjects *Physics* and *Chemistry* and to the legitimating power of the external examination.

The Links Between Gender and Science-for-All

As indicated earlier, no previous analysis of science-for-all curricula has made the link between these curricula and gender. Clearly, however, the essence of a science-for-all curriculum, as depicted by Fensham (1985) and as operationalised in at least the two examples discussed in the preceding section of this chapter, reflects in many ways the image of gender-inclusive science developed in Chapters 4 and 5. This is especially the case in relation to characteristics such as personal and social relevance, recognition of diversity in prior learnings and experiences, and provision of a variety of forms of assessment. The tendencies for science-for-all curricula to be multidisciplinary and to

include social and environmental applications provide other points of commonality. Despite these clear links, however, gender was not an issue in the initial arguments for the need to reform traditional science curricula to make them more suitable for "all" students. Nor was it an issue in the analyses carried out of the development and implementation of these subjects. Whether females were not considered important or whether they were considered to be part of the group of "all" students is not clear. As Yates (1988, p. 41) has asked previously, "Does 'all students' include girls?"

What is clear from other research, as discussed in Chapter 4, is that any assumptions that programs "for all" would address the problematic relationship between gender and science were fallacious. As demonstrated by the evaluative research of Malcom (1984), specific targetting of gender-inclusiveness is necessary if the programs are to be successful in influencing the way in which females relate to science, if females, indeed, are to be part of the group of "all" students participating in science.

THE CASE OF *PHYSICAL SCIENCE* IN WESTERN AUSTRALIA

Background

Against the background of previous attempts to introduce an integrated code, science-for-all subject into the upper secondary curriculum, *Physical Science* was introduced in Western Australia in 1978. The introduction of the subject represented a break with tradition in a number of ways, not the least of which was that it was the first attempt by the State school system (the Education Department of Western Australia) to take the initiative in upper secondary science curriculum development. All existing science curricula had been initiatives of

groups in the university sector. Further, the universities continued to retain considerable power over all of these upper secondary school subjects, through the various Syllabus Committees and through their dominance of the Tertiary Admissions Examination (TAE).

The records of the Physical Science Evaluation Project (Dynan, Parker & Ryan, Document RE/DPR/012, July, 1978) indicate that the Education Department's initiative had begun as far back as 1972. As in Victoria, there was a groundswell of opinion regarding the need to break the hold of the "big four" subjects on the upper secondary curriculum, especially in the context of increasing retention of students into Years 11 and 12, and a further perceived need for a more relevant, socially oriented and participatory science curriculum.

Initial discussions between representatives of the Education Department and members of the Departments of Physics and Chemistry at The University of Western Australia, regarding the need for such a course, were described by an Education Department representative as resulting in a "state of impasse" (Dynan et al, 1978, p.2). Following this, the Education Department initiated a survey of schools to gather more evidence about the need for the subject. The report of this survey, known as the "Green Document" (because of the color of its cover, not because of its authorship) was published and circulated widely (Education Department of Western Australia, 1975). The report recommended (p. 2) that "a matriculation level TAE Physical Science Course be developed and implemented in schools as soon as possible" and that "there is a need for a science course or courses for non-tertiary oriented students".

Despite the recognition (Education Department of Western Australia, 1978, p.1) that the first of these recommendations "presented some difficulties due to the prevailing attitudes of certain tertiary personnel", the Department decided to give this recommendation first

priority. It undertook a review of all available Physical Science courses and decided that the Victorian course, *Physical Science: Man and the Physical World* offered the best starting point for the development of a suitable course for Western Australia. Two committees were set up to advise on the modifications needed in the Victorian course. One committee consisted entirely of practising teachers, who worked together to produce the course outline. The other committee consisted of representatives from many groups involved with or affected by secondary education (including some from the more conservative tertiary institutions) and acted like a committee of review. The syllabus statement produced by these two committees was approved for certification, by the then Board of Secondary Education, and, following protracted debate, also was approved by the Tertiary Education Commission for examination in the TAE. The new subject was introduced in 20 selected schools in 1978 and offered Statewide in 1979.

The Extent of Change from a Collection Code to an Integrated Code

Essentially, as in Victoria, the introduction of *Physical Science* represented a break away from the traditional single-discipline science curriculum structure, a structure which had prevailed in Western Australia for over 60 years. Also, as in Victoria, the new subject was intended to provide students with a single subject alternative to the two established, collection code subjects *Physics* and *Chemistry* and to give them greater flexibility in their choice of studies. Partly in response to concerns about the perceived abstract nature of the then current *Physics* and *Chemistry* courses, *Physical Science* incorporated practical problems, and technological and societal issues. The course materials reflected this emphasis by relating scientific principles to examples from students' everyday lives, and by recommending a teaching approach which

included a large proportion of practical work (30 percent of class time, compared with 20 percent or less in *Physics* and *Chemistry* as then taught). Information accompanying the new subject stressed that, while it clearly had a different emphasis from the established subjects, it was to be regarded as equal to them in both status and conceptual difficulty. The high status of the subject was considered to be sealed officially by its acceptance, apparently on equal terms with *Physics* and *Chemistry*, into the fold of collection code TAE subjects.

In prospect, *Physical Science* was intended to represent a much greater shift from the collection code than it did ultimately. Its development, in a sense, was overtaken by the phenomenon described by Goodson (1983) and alluded to earlier in this chapter: the developers, in attempting to establish the legitimacy of *Physical Science* as a TAE subject, had shifted it more towards the traditional academic tradition than had been intended initially. Thus, although, in Bernstein's terms, the content of *Physical Science* was intended to be significantly less strongly classified than that of the traditional collection code physical science subjects, the weaker classification, in reality, derived from a fairly direct, rather than integrated, combination of knowledge from traditional physics and chemistry courses, and the references to social and environmental applications. Further, with respect to Bernstein's framing, the shift was even less than for classification. Although the pedagogy included a greater emphasis on practical work and discussions, because of its TAE subject status, the assessment remained strongly oriented towards the pen-and-paper external examination and focused on scientific knowledge and science process skills. Assessment in the affective domain, although alleged to be an important aspect of *Physical Science*, was, as for all TAE science subjects, not permitted.

Responses to the Implementation of *Physical Science*

In 1978–1980, an extensive formative evaluation of the introduction, development and implementation of the new course, the *Physical Science Evaluation Project*, was carried out. Detailed reports of the project can be found elsewhere (Boud et al, 1979; Dynan et al, 1979). In addition, a preliminary analysis of students' perceptions of the new subjects was reported by Andrich and Parker (1980). The latter analysis demonstrated the gap between rhetoric and reality in relation to *Physical Science*. As in the two cases of integrated code science subjects described in the previous section of this chapter, the official status of *Physical Science* as a TAE subject never was accepted wholeheartedly by the State's tertiary institutions. Although until 1986 there were no declared prerequisites for tertiary studies in science and engineering, there remained plenty of unofficial encouragement for secondary students to continue to present for tertiary study with TAE *Physics* and *Chemistry*. Moreover, at the school level, neither students nor teachers appeared to believe the official information advising them that *Physical Science* should be accepted on equal terms to *Physics* and *Chemistry*. In addition, schools, even if enthusiastic about the new subject, were usually not in a position to be able to substitute it for one of their existing offerings. It needed sufficient commitment from the school for it to be timetabled as an extra subject, in a timetable seen as already strained to the limit by many competing demands.

For at least all the above reasons, enrolments in *Physical Science* consistently have remained relatively low (e.g. rarely higher than 4 percent of the total examination population, a number which is equivalent to between 20 and 25 percent of the number enrolled in *Physics*). In an overall sense, the introduction of *Physical Science* in Western Australia represents a relatively unsuccessful attempt to

provide an alternative science course above the existing level of containment. *Biology* or *Human Biology* have continued, inappropriately, to be the science subjects taken by those requiring a more general science subject in upper secondary school, and, as is shown in Chapter 7 and 8 of this thesis, the sex-related imbalances evident in students' upper secondary science education have remained.

The Issue of Status and the Issue of Gender

Of particular interest to this study was that, although the shift was not large, in comparison to *Physics* and *Chemistry*, *Physical Science* was somewhat weakly classified and framed, and in general was more representative of Bernstein's integrated code and Young's low status knowledge. In this context, the question arose as to whether, despite efforts to ensure relatively high status for this more practical and socially relevant subject, its status would be seen as relatively low, and moreover, as a consequence of these perceptions, it would be made accessible to and selected by students defined as less "able" or less "worthwhile". The following analysis provides some answers to these questions. The data used in this analysis have been extracted from those gathered during the *Physical Science Evaluation Project*. This particular analysis focused on only two small sections of the data gathered, namely, the students' perceptions of the relative difficulty of *Physical Science*, and the distribution and ability of boys and girls studying the new subject. It should be noted that the original data were not collected explicitly to confirm or refute any hypothesis. The intention at the time was simply to gather information from students to contribute ultimately to a multi-dimensional view of the innovation. The analysis and interpretations presented here have been developed subsequent to the main evaluation.

The Perceived Status of *Physical Science*

Students enrolled in *Physical Science* (Year 11) in 1978 (396 students) and 1979 (650 students) were asked to rate whether each of the following subjects – *Mathematics I, Mathematics II and III, Mathematics IV, Physics, Chemistry, Biology and Human Biology* – was *much easier, easier, about equally difficult, more difficult, or much more difficult* than, *Physical Science*. As well as answering this structured rating question, all students were given the opportunity to express freely their perceptions of the new subject, in written form, and in interviews (conducted in groups and with selected individuals). Although the question posed formally to the students concerned only the relative difficulty and not the status of the various science and mathematics subjects, interview data and written comments revealed that to students "more relevant" (which was intended for *Physical Science*) necessarily implied both "lower status" and "less difficult" (neither of which was intended for *Physical Science*). The students did not appear to make any distinction between status and difficulty; their perceptions of a subject as "easy", "a soft option", "not really good enough for university courses" and "can't really be a full TAE subject" were inseparable. It would appear, then, that the available measure of perceived relative difficulty also can be taken as an indicator of perceived status.

The analysis showed that the initial impressions of the first and second cohorts enrolling in *Physical Science* were very similar, and that both cohorts perceived *Physical Science* to be substantially "easier" than either *Physics* or *Chemistry*. Thus, the entering perceptions of the first two cohorts of students were not consistent with the official information available about the new subject. This information appeared to be only one input to the students' construction of the reality of *Physical Science*.

Gender Issues and *Physical Science*

Following Young's arguments, it would be expected that this subject, seen to be of relatively low status compared with *Physics* and *Chemistry*, would be seen also as more suitable for students who are considered as relatively less "worthwhile" or "able" than *Physics* and *Chemistry* students. Initial impressionistic evidence suggested that this could well be the case. Of the 20 schools offering the subject in 1978, very few could be designated as Government or non-Government schools with students from predominantly high socio-economic status backgrounds and, as shown in detail in Chapter 8, this imbalance was not rectified to any great extent in subsequent years.

It was also evident that a higher proportion of *Physical Science* students were girls than was generally the case with *Physics* and *Chemistry*. Specifically, nearly 36 percent of the the first cohort and 39 percent of the second cohort in *Physical Science* were girls, compared with, at that time, 26 percent girls in *Physics* and 31 percent girls in *Chemistry*. In this regard, further analysis of sex-related differences in perceptions and abilities of the original *Physical Science* students revealed a number of interesting features.

First, as a group, the girls in the original intake of 396 students had achieved significantly higher than the boys in both *Science* and *Mathematics* at Year 10 level. The majority of these girls had achieved the highest possible grades (Advanced Credit or Advanced Pass) in both subjects. That is to say, on these achievement criteria, which might be expected to provide the basis for selection and allocation of students to upper school courses, there was every indication that the girls in question could have studied and succeeded in TAE *Physics* and *Chemistry*.

Second, when the original 396 students were asked to indicate which people had influenced them either "very strongly" or "quite

strongly" to do *Physical Science*, approximately 24 percent named a guidance officer and 33 percent identified a science teacher. The vast majority of these two subgroups were girls. Hence it appeared that, despite the fact that they had demonstrated high ability in science and mathematics, girls were being counselled to take *Physical Science*, whereas boys of comparable or even lesser ability were being urged to enrol in what were known colloquially as the "big four" (*Physics, Chemistry, Mathematics II* and *Mathematics III*), in order, as one guidance officer expressed it, to "keep their options open at the tertiary level". Girls, it appears, were not seen to need the "big four". The following comments made by some of these able girls indicate the kind of advice they received:

The guidance officer advised me that Physical Science would be better for me because it had less Physics.

For the course I wish to study at university I required a good science background and I felt I would not be able to cope with Chemistry and Physics so I took this.

My teacher advised me to try Physical Science. I don't feel confident to take Chemistry and Physics.

My science teacher said it is a more general course and I would enjoy it more.

Third, a comparison between the perceptions of boys and girls indicated that the girls perceived *Physical Science* to be relatively more difficult and higher status than the boys and had a significantly lower expectation of success in the subject than the boys. These differences in perception are surprising, given the fact that the girls as a group had previously demonstrated higher ability than the boys in both mathematics and science.

A Sociology of Knowledge Perspective on the Status and Gendering of *Physical Science*

To some extent, explanation of the evidence regarding the status and gendering of *Physical Science* phenomena is assisted by the view of a school subject as a cultural product. Following Mannheim (1936), *Physical Science* can be viewed as a cultural product displaying three distinct strata of meaning: (a) the official meaning, present prior to interpretation by the human beings involved; (b) the expressive meaning, reflecting modification of the official information through participants' interpretative processes; and (c) the documentary or evidential meaning, the broader conceptualisation of the subject as a cultural product.

The "official" meaning of *Physical Science* was made explicit in the documents made available to students and teachers by the Western Australian Education Department, documents which designated the status of the subject as "high" and equal to that of *Physics* and *Chemistry*. In Mannheim's terms, however, these documents did not *convey* meaning, but rather *displayed* meaning. The meaning actually conveyed to students – the "expressive" meaning – was mediated by the students' interpretative processes. These in turn were influenced by the students' previous "knowledge", acquired in a variety of ways during their earlier socialisation, and reinforced by teachers and guidance officers, as demonstrated above. It appears that in this case the students and their teachers interpreted some aspects of the displayed information about *Physical Science* in such a way that the expressive meaning of the new subject carried connotations of "low status" and "more suitable for girls", relative to *Physics* and *Chemistry*. The theoretical framework developed in this present study would suggest that the relevant and practical

dimensions of the new subject were crucial in this mediating, interpretative, "coding" process.

It is in the "documentary" meaning, however – the broader conceptualisation of the cultural product, incorporating many other manifestations of similar kinds of observed and interpreted phenomena – that the gender coding of *Physical Science* becomes obvious. The status and gendering of *Biology* and *Human Biology*, perhaps the most "relevant" upper school science subjects in the Western Australian curriculum, had been established for many years. It appeared that students coded the new subject in accordance with this previous experience of the "more relevant/low status/suitable for girls" phenomenon. This combined evidence then enabled them to crystallise out a generalised view of high and low status school subjects (and the kinds of students who typically studied these subjects) – the documentary meaning alluded to by Mannheim and the "gender code" theorised in this present study.

In terms of the definition of "code" used in this thesis (Bernstein, 1990), this study of the early years of the implementation of *Physical Science* has demonstrated the apparently tacit acquisition of the gender code by students and the way the code regulates students' perceptions of knowledge distribution in the context of school science subjects. In the case of *Physical Science*, the gender code – the "expressive" and "documentary" meanings attributed to the new subject by students – appeared to be quite powerful. It was shown to be much more powerful than the official meaning and, indeed, resistant to change by further officially displayed information. This kind of power, in a sense, was foreshadowed by Young when he argued that

if pupils do identify high status knowledge as suggested ...
they could well come to reject curricular and pedagogic

innovations which necessarily involve changing definitions of relevant knowledge and teaching methods.

(Young, 1971a, p. 36)

While *Physical Science*, as an innovation, by no means was rejected *per se* by students, they appear to have been reluctant to come to terms with a modified definition of high status knowledge. Further, they readily grafted the new subject onto their existing schema for placing subjects in terms of the subjects' status and the kinds of students who are expected to study them. In other words, they interpreted information and experience regarding the new subject in terms of their existing gender code.

SUMMARY

This chapter has reported the first stage of the testing of the theory of the gender code of school science. It focused on the gap revealed by the review of empirical research in Chapter 4, namely, the gender effect of structural, policy-level changes to the curriculum and assessment of individual science subjects at the senior secondary level. Using the example of the implementation of the more integrated code subject *Physical Science* in Western Australia in 1978–1979, it explored the extent to which the availability of this subject appeared to make a difference to the relationship between gender and science. In so doing, it revealed also the close similarity between curricula aimed at science-for-all and curricula aimed at gender-inclusiveness. It demonstrated, however, that, although these two kinds of curricula have many characteristics in common, this similarity has not been made explicit before. Further, and partly as a consequence of the lack of recognition of the similarity between the two, the potential of science-for-all curricula in relation to gender-inclusiveness appears neither to have been understood, nor to

have been realised fully. It was pointed out that full realisation of this potential requires attention to Malcom's (1984) finding that specific targetting of gender-inclusiveness is necessary if the programs "for all" are to be successful in influencing the way science is perceived and the way females and males relate to science.

The findings reported in this chapter lend support to the Bernstein/Young sections of the gender code model proposed in Chapter 5, especially the dimension concerned with status, as proposed by Young (1971b). At the level of individual subjects, the more relevant, less individualistically-oriented, integrated code subject *Physical Science* (in both Western Australia and Victoria) was perceived to be less difficult and of lower status than its traditional, unrelated, individualistic, collection code counterparts *Physics* and *Chemistry*, despite the official information advising to the contrary. This perception, moreover, appeared to be both pervasive and powerful, shared by students and guidance officers alike, though held less powerfully by female students than by male students. These perceptions appeared also to have led to *Physical Science* being seen as more suitable than *Physics* and *Chemistry* for girls, even for girls who had demonstrated high ability in science and mathematics.

The evidence points towards a gender coding of school science subjects, with a code defined, in Bernstein's (1990) terms as "a regulative principle, tacitly acquired, which selects and integrates relevant meaning, forms of realizations and evoking contexts" (p. 101). In this sense the attributes of various school science subjects can be seen as a system of symbols. To this point, the gender coding of these subjects has been demonstrated in the association of maleness with subjects which have the attributes of Bernstein's collection code and Young's high status knowledge, and the complementary association of femaleness with

subjects more characteristic of Bernstein's integrated code and Young's lower status knowledge.

Further evidence, presented in the following chapter, highlights aspects of gender coding associated with participation and achievement of males and females at the level of the total science curriculum. Chapter 8 then explores additional dimensions of the gender code, including especially the dimension associated with Broadfoot's typology of different modes of assessment.

Chapter 7

GENDER CODING IN THE WESTERN AUSTRALIAN SECONDARY SCIENCE CURRICULUM: OVERVIEW 1969–1993

INTRODUCTION

Purpose and Background

This chapter provides an overview of sex differences in participation and achievement in secondary school science under the various system-wide curriculum and assessment structures operating in Western Australia during the period 1969–1993. Thus, the chapter focuses on the second of the two gaps in research revealed by the review of empirical research in Chapter 4, namely, the gender effect of different system-wide structures for science curriculum and assessment. The main purpose of the chapter is to test aspects of the gender code theory associated with the interaction between the system-wide design of curriculum and assessment and patterns of sex differences in study and achievement in science. In addition, the chapter provides the overall background to Chapter 8, which focuses more specifically on the years 1986–1993.

Throughout this chapter it is important to be mindful of the overall picture of school science in Western Australia during the period of this study. As indicated in Chapters 1 and 2 of this thesis, for the 17 years between 1969 and 1986, the lower secondary school science curriculum was part of the compulsory, multidisciplinary, school-

assessed core of the Achievement Certificate; after 1986–1987 it was part of a unitised curriculum structure, which required students to choose their science studies from a range of specified units. During the same period, the upper secondary school science curriculum had continued with the long-established tradition of separate science subjects, represented most recently as the seven subjects of *Biology*, *Chemistry*, *Human Biology*, *Physics*, *Geology*, *Physical Science* and *Senior Science*.

Thus, in Bernstein's terms, although the lower secondary curriculum was an integrated code curriculum, the upper secondary curriculum as a whole was a typical collection code curriculum. It was strongly classified, with strong boundaries between subjects, and except for *Senior Science*, tied to the State-wide external examination (the TAE or TEE). As shown previously in Figure 2.2, as individual subjects, these science subjects spanned a range from very strong collection code (*Physics*, *Chemistry* and *Geology*, each with relatively 'pure' forms of scientific knowledge) to less strong collection code (*Biology*, *Human Biology* and *Physical Science*, each of which included some emphasis on multidisciplinary science) to *Senior Science*, a strongly integrated code subject. This curriculum structure forced students to face a choice point at the end of their lower secondary years. Those choosing to continue their schooling and to continue with science chose one or more of the seven upper secondary science subjects, typically for a further two years of study. As demonstrated by Parker (1987) between 70 and 80 percent of students chose at least one science subject and many chose two (for example students tended to study *Physics* and *Chemistry* as a pair).

The collection code upper secondary science curriculum was only one part of what Andrich (1989) has pointed out was a relatively "fast track" upper secondary school system, designed essentially for the tertiary bound student. Such a student was expected to progress through the

system sequentially and rapidly, to succeed in the minimum time and, if selected for tertiary studies, to be well prepared for such studies in a substantive (science) content sense. Andrich argued also that the success of students in coping with this kind of system "depends on the students being able, being motivated and having a supportive out-of-school environment, which includes access to help and opportunities to study at home" (p. 16). He called such students "highly educationally resourced" and noted that, frequently, this term was synonymous with high socio-economic status and with "tertiary bound". As is shown later in this chapter and in Chapter 8, in terms of the gender code theory developed in this study, "highly educationally resourced" emerges, in part, as also synonymous with male.

Outline of the Chapter

This chapter focuses initially on the Achievement Certificate curriculum and assessment structure, which operated in Years 8–10 of secondary schooling in Western Australia between 1969 and 1986, and on previous studies of the pattern of sex differences in science participation and achievement which emerged under this structure. That pattern is contrasted with the one which developed under the Unit Curriculum structure introduced at the lower secondary level in 1987–1988. The point is made that, although the science curriculum under both structures was representative of an integrated code curriculum, one feature of the Unit Curriculum structure shifted it more towards the collection code than the previous Achievement Certificate structure. This structural feature involved the lowering of what Fensham (1985, p. 422) called the "level of containment" (as explained in Chapter 6) and the increased capacity for students to exercise more choice in determining what kind of science they wished to study. This chapter demonstrates the apparent consequences of

the shift in level of containment for the relationship between gender and science and discusses these consequences in terms of gender code theory.

The chapter then focuses on data gathered and analysed specifically for this study, concerning the transition from lower secondary to upper secondary schooling during the period 1976–1993. Detailed information on students' participation and achievement in the various science subjects is presented and discussed. The subject-centred, externally assessed, upper secondary science curriculum (a collection code curriculum) is contrasted with the multidisciplinary, school-assessed, lower secondary curriculum (the integrated code curriculum described earlier) with particular reference to the implications of these two contrasting models for the relationship between gender and science. Again the point is made that the pattern of subject choice confirms particularly the aspects of gender code theory associated with Bernstein's collection and integrated codes. Questions also are raised regarding the gender coding of students' science achievement, questions which are explored in greater depth in Chapter 8.

LOWER SECONDARY SCHOOL SCIENCE 1969–1990

The Achievement Certificate Structure, 1969–1986

Under the Achievement Certificate curriculum structure, *Science* was one of four 'core' subjects defined for compulsory study, the others being *English*, *Mathematics* and *Social Studies*. Virtually all students studied each of these core subjects for approximately four hours per week of effective programmed school time during Years 8, 9 and 10; the remainder of their total programme of study was selected from a range of optional subjects covering other areas such as *Home Economics* and

Manual Arts. Assessment in all subjects was entirely school-based and continuous throughout the year.

The *Science* syllabus studied was a typical science-for-all model. As indicated earlier, in Bernstein's terms, its weak classification and integrated code are clearly recognisable. It was a topic-centred, multidisciplinary course covering the fundamentals of physics, chemistry, biology, earth sciences and astronomy. The school-based assessment culminated in grades representing students' cumulative achievement throughout the whole year of study. The course was approved for State-wide implementation and certification by the central certifying body known, before 1985, as the Board of Secondary Education and, after 1985, as the Secondary Education Authority. This statutory authority was also responsible for ensuring that the grades awarded to students for achievement in *Science* were comparable across all schools in the State.

The Achievement Certificate structure, with its in-built regulatory mechanisms, provided an unusual degree of uniformity throughout the State in relation to time spent on science, science courses studied, and assessment and grading of student achievement in science. Thus, from a research perspective, in making comparisons between the achievement of different groups of students in science, there was a considerable degree of certainty regarding the amount of science students had studied, the nature of the science studied and the grading procedures used.

Parker and Offer (1987) have studied these kinds of comparisons between female and male students, providing a detailed analysis of the trend in sex differences in science achievement over the period 1972–1986. Their analysis demonstrated that, while at Year 10 level in 1972 the mean achievement of males in *Science* was significantly higher than that of females, by 1979 females and males were achieving equally well in

science and from 1980–1986, females consistently out-achieved males in this area. Parker and Offer noted that the latter, six-year period of higher achievement by females was associated with the implementation of a variety of gender and science intervention strategies and awareness-raising programmes in Western Australia (as outlined in Chapter 1 of this thesis).

In discussing their findings, Parker and Offer contrasted the situation of no sex differences in science achievement amongst Western Australian 15-year-olds with the many other findings of higher male achievement in this age group (e.g. IEA, 1988; Kelly, 1978; Matyas, 1985). They noted that none of the studies reporting boys' higher achievement had attempted to control for boys' and girls' science educational experience prior to the administration of the relevant test. They emphasised that such controls, which, because of the structure of the Achievement Certificate curriculum, existed fortuitously in Western Australia during the period 1972–1986, were likely to be particularly significant, given the qualitative and quantitative difference in science education received typically by boys and girls in most parts of the world. In essence, the regulated system in Western Australia provided a controlled situation for testing, post hoc, a differential coursework hypothesis, as noted in Chapter 4 of this thesis. As in the Fennema and Sherman (1977) study of sex differences in mathematics achievement referred to in Chapter 4 of this thesis, Parker and Offer found that sex differences in science achievement disappeared when boys' and girls' course-taking backgrounds were identical.

An aspect of the Achievement Certificate structure not explored by Parker and Offer concerns assessment. Importantly, assessment provides another basis for comparison between the Western Australian lower secondary school data and those obtained elsewhere in the world. The

Western Australia data were based on continuous, year-long assessment. Although, in the earlier years of the Achievement Certificate structure, the teacher-made tests used in school assessments were strongly reminiscent of the former Junior Certificate examinations, as teachers became more comfortable and skilled in implementing school-based assessment, their procedures included, increasingly, a variety of assessment modes. By contrast, the NAEP data reported by Matyas (1985), the IEA data analysed by Kelly (1978) and the data available from many other studies of science achievement, were based on one-off, externally administered, mainly multiple-choice tests. As was pointed out in Chapter 4 of this thesis, the latter mode of assessment tends to depress the results of girls, and thus to exaggerate sex differences in achievement in boys' favour. The contrast between the sex differences in students' achievement in science under the school-assessed Achievement Certificate structure, and that in the one-off tests which form the basis of much other research on students' achievement, raises questions regarding aspects of the gender code associated with Broadfoot's typology of informal and formal modes of assessment. These questions are explored further in Chapter 8.

Important also to the study reported in this thesis is the finding of Parker and Offer (1987) that, when they shared their information on trends in lower secondary school achievement with others in the education community, they were greeted initially with disbelief. Many people found it difficult to accept that girls could achieve as well as, if not better than boys in science (and the same also applied to the parallel data for mathematics). When finally convinced that the data covered all students throughout the State and were from official State-wide records of student achievement, reactants attempted typically to explain away girls' higher achievement with comments to the effect that girls were neater,

more likeable and/or more compliant students than boys and therefore were given higher marks by teachers. Clearly, as found by Walkerdine (1989) in relation to girls' success in mathematics, an association between femaleness and high achievement in science was not one with which many people were comfortable.

In summary, then, a highly regulated, compulsory, multidisciplinary curriculum, with student performance measured by school-based, continuous assessment, operated in Western Australia at lower secondary school level between 1969 and 1986. This kind of integrated code, science-for-all curriculum appeared to facilitate the exposure of all students to a broad range of scientific knowledge, and to facilitate equality of science outcomes for males and females in terms of both curriculum content and demonstrated mastery of that content. This effect, moreover, appeared to be enhanced by intervention programs which addressed concerns related to gender equity in science and as teachers gained experience with school-based assessment. It was an effect, however, which many people found to be problematic and which they tried to explain by linking it to factors other than capacity to succeed in science as such.

The Unit Curriculum Structure, Introduced 1987–1988

As referred to in Chapter 1 of this thesis, the Beazley Report (Western Australia, 1984a), recommended substantial reforms to lower secondary schooling in Western Australia, and as a result of these recommendations a Unit Curriculum structure was introduced in 1987–1988. The new structure involved the repackaging of the former year-long Achievement Certificate courses into 40-hour units, and allowed students to select their Year 8, 9 and 10 programs of study from a large number of units (over 600 units in 1988) covering seven major areas

(called "components") of the curriculum. The assessment procedures for the Unit curriculum remained, as in the Achievement Certificate, school-based and continuous (in Broadfoot's terms, characteristic of informal assessment and thus weak framing).

Structurally the Unit Curriculum required students to select approximately twenty-four 40-hour units in each of Years 8, 9 and 10, including at least one from each of the seven components. *Science and Technology* was designated as one component and about 35 *Science and Technology* units, covering a wide range of content, were made available. However, given that some of these units essentially were information technology units containing no science at all in the traditional sense, it was possible, theoretically, for students to do almost no science. In practice, most schools set a required minimum number of units to be done in each curriculum component, which in the case of *Science and Technology*, was usually between one and three each year. Thus, in comparison with the Achievement Certificate structure, the Unit Curriculum structure allowed for a significant reduction in the mandatory amount of science. The requirements of the Achievement Certificate had resulted in all students studying science for the equivalent of about four units during each of the three years of lower secondary school (i.e. a total equivalent to 12 units). Under the Unit Curriculum, with the relaxation of these requirements, the number of mandatory science units to be studied by a student was reduced to, at most, 9 units. Moreover, while previously all students had studied topics from all major science disciplines, the new structure allowed students, especially at Year 10 level, to avoid some disciplines altogether and, conversely, to specialise earlier in others. In terms of the theoretical models discussed earlier on this thesis, the Unit Curriculum can be seen as a shift away

from a science-for-all, integrated code model and a lowering of the level of containment from Year 11 level to Year 9 level.

From the perspective of this thesis, an important point is that the Unit Curriculum allowed students more choice. Again in terms of the theoretical framework introduced in Chapter 2, the requirement for students to choose their science studies from a range of optional science units, and thus to define more clearly the boundaries of their "subjects" (in this case, topic-centred units), is one attribute of a strongly classified curriculum structure. On this basis, although the Unit Curriculum structure retained many features of the integrated code Achievement Certificate structure (including, as indicated earlier, the weakly framed assessment procedures), it acquired the feature of "more choice", a feature associated with and, indeed essential to, strong classification and the collection code. This shift is demonstrated diagrammatically in Figure 7.1, which shows the placement of Achievement Certificate Science and Unit Curriculum Science in terms of the theoretical framework developed in Chapter 2 of this thesis. An important question associated with the shift arises regarding the enrolment and achievement of males and females in the more collection code Unit Curriculum compared with the more integrated code Achievement Certificate.

Rennie and Parker (1993) have described in detail some of the effects of the Unit Curriculum structure on science outcomes, using data gathered during the pilot of the new structure in 1987 and from its State-wide implementation in 1988–1990. Four major points emerged from their analysis. First, in comparison with the years 1969–1987, students studied less science under the Unit Curriculum, with a reduction of between 10 and 15 percent in the average time spent on science. Second, this reduction was more marked for females than for males. Third, patterns of unit choice were sex-stereotyped, with, for example, girls

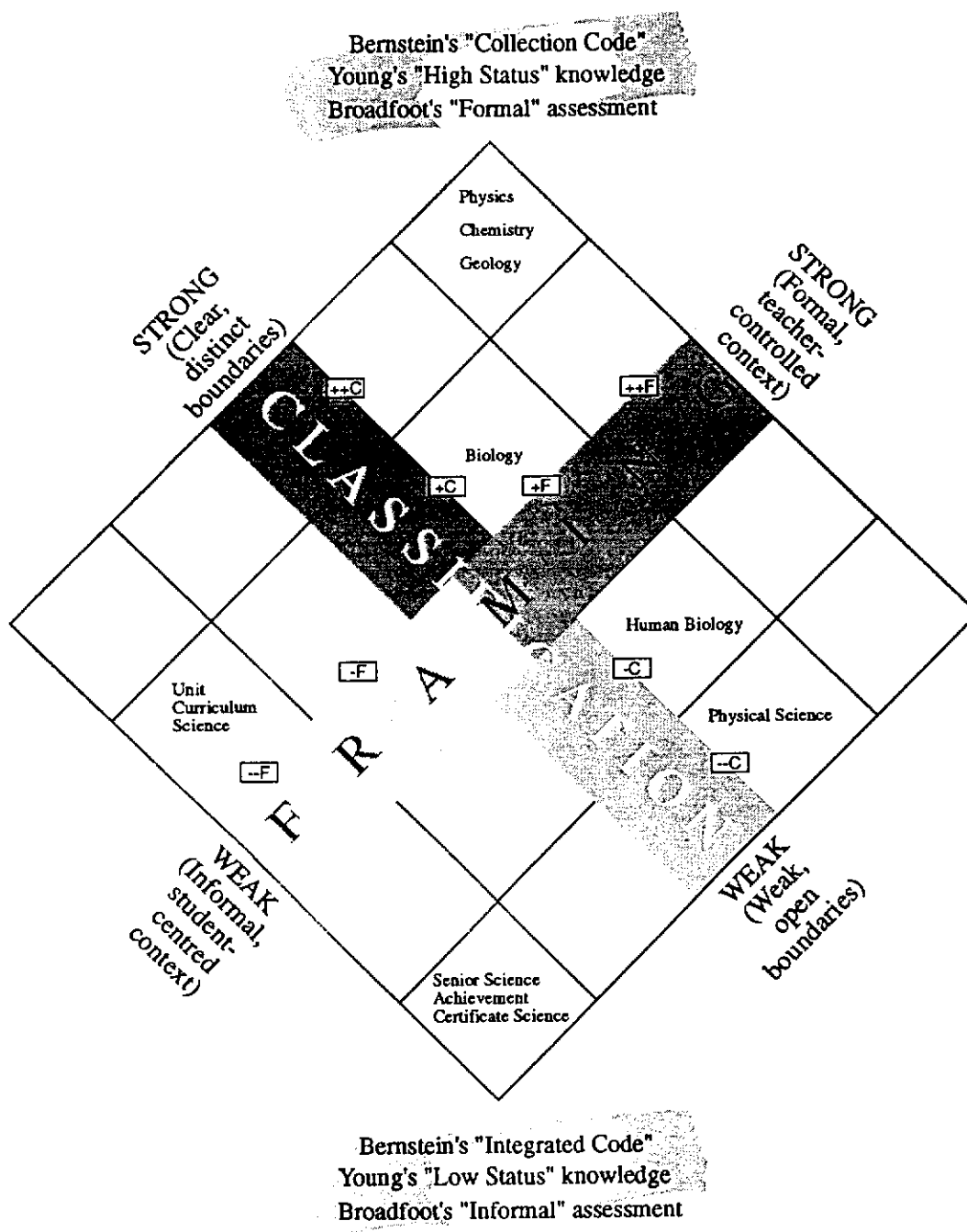


Figure 7.1. Reconceptualisation of the Bernstein/Young/Broadfoot models, showing location of upper and lower secondary science syllabuses, Western Australia, 1969–1993.

seriously underrepresented in *Forces, Motion and Energy* and in *Mining, Chemistry and Industry*, (units regarded as essential prior study for upper secondary *Physics* and *Chemistry*), and boys underrepresented in *Ecology* and in *Biological Change*. And fourth, there was little change to the pattern of sex differences in achievement which had been characteristic of the later years of the Achievement Certificate. Specifically, under the Unit Curriculum, females achieved slightly higher than males in the physical science units, and considerably higher in the biological science units.

In summary, in terms of the gender code theory developed in this study, the major difference between the Achievement Certificate and Unit Curriculum structures was that the latter, more strongly classified curriculum, had lowered the level of containment, so that the average age at which choice was exercised became 13.5 years rather than the previous 15.5 years, thus allowing the consequences of gender-stereotyped science subject choice to take effect even earlier in students' lives than previously. This example of the apparent consequences of a shift towards a more strongly classified curriculum, small though that shift was, and affecting, as it did, only one aspect of classification, provides further evidence confirming the theory of the gender code of school science, developed in the Chapters 2–5 of this thesis. Specifically, in this case, it provides further evidence of the association of maleness with Bernstein's collection code and of femaleness with Bernstein's integrated code. This analysis demonstrates also that the pattern of high science achievement by girls, which had become established under the Achievement Certificate, did not change under the Unit curriculum. As predicted from the gender code theory, a weakly framed, informal assessment structure continued to allow girls to demonstrate high achievement in science.

THE TRANSITION FROM LOWER SECONDARY SCIENCE TO UPPER SECONDARY SCIENCE

Participation in Upper Secondary School Science

Overall trends, 1976–1993

Reference was made earlier to the curriculum events surrounding the transition of students in Western Australia from Year 10 to Year 11, (the choice point), and the dramatic change in curriculum structure at this juncture, from multidisciplinary, topic-centred, school-assessed, integrated code to clearly defined, subject-centred, externally assessed, collection code. In the context of this study, it was important to analyse this transition using gender as a central category of the analysis. For this purpose, enrolment and achievement data, for each upper secondary science subject during the period 1976–1993 were obtained from the Secondary Education Authority. As indicated earlier, the years 1986–1993 will be the focus of a more detailed discussion in the next chapter. The purpose in this section is to provide an overview of the whole 18 years. Thus, Figure 7.2 presents the overall historical perspective on science enrolments, showing, for each of the years 1976–93,

- the total number of full-time Year 12 students in Government and non-Government schools
- the total Year 8 cohort to which the Year 12 numbers relate (i.e. Year 8 numbers four years earlier)
- the total number of students enrolled in each science subject, with the exception of *Geology*, where enrolments in most years are below 100 students.

It should be noted that the Year 8 and Year 12 cohort numbers in Figure 7.2 relate to full-time school students. The science enrolments, however, are based on data which include, in addition to typical secondary school

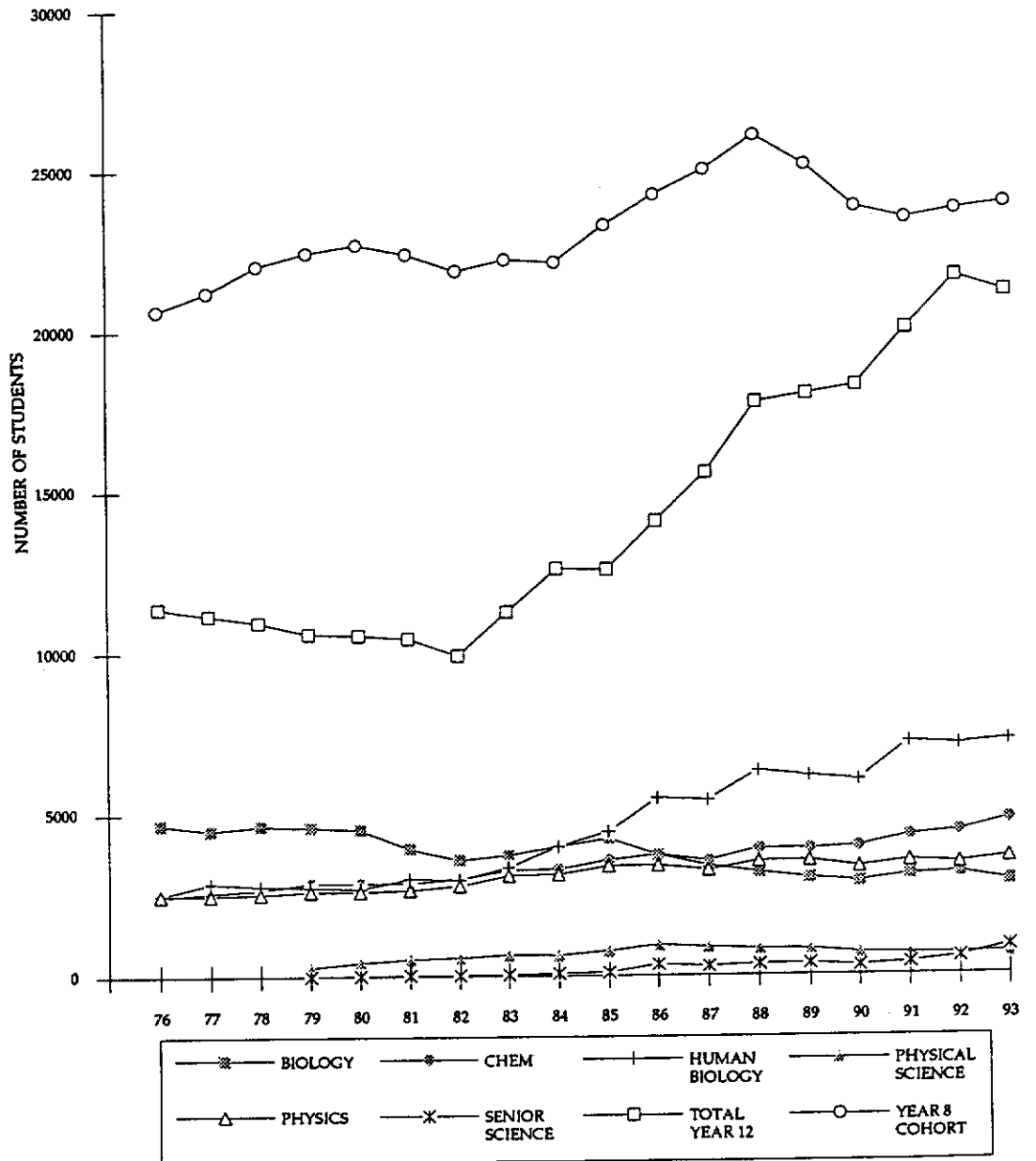


Figure 7.2. Western Australia, 1976–1993: Number of Year 12 school students, number of students in relevant year 8 cohort and numbers of students enrolled for examination/certification in six upper secondary school science subjects.

students in Government and non-Government schools, a significant number of students from Colleges of Technical and Further Education (TAFE), Senior Colleges and private colleges with fee-paying overseas students. Because students in the latter group may be repeating Year 12 studies, or may have entered the system since Year 8, it is not possible to translate the Year 12 enrolments in Figure 7.2, in any meaningful way, into a percentage of a Year 8 or Year 12 school cohort. [In this thesis (e.g. in Chapter 8) where a science enrolment is represented as a percentage of a total Year 12 cohort, the numbers relate to the number of students enrolled for certification or examination in the subject.]

Figure 7.2 demonstrates that, as is widely recognised and, as has been demonstrated for other Australian States by, for example Dekkers, de Laeter and Malone (1991),

- there has been a large increase in retention of students into Year 12 in Western Australia in recent years, dating from approximately 1983;
- the major science subjects in Western Australia have been, for many years, the TAE/TEE subjects *Biology*, *Chemistry*, *Physics* and *Human Biology*;
- enrolments tend to be relatively low in *Physical Science* (also a TAE/TEE science subject) and in the one totally school-assessed science subject (shown as *Senior Science* in Figure 7.2, but prior to 1985 named *CSE-General Science*), although the numbers in *Senior Science* increased considerably in 1993.

Trends According to Sex of Student

From the point of view of this study, it was of interest also to analyse the enrolments differentially according to students' sex. The

proportions of females and males in the examination population in each science subject in each of the years 1976–1993 are shown in Figure 7.3 and Table 7.1, with the latter showing also, for comparative purposes, the total number of females and males in the Year 12 cohort. The data reinforce what has been demonstrated in a number of previous reports (Parker, 1986; Parker and Offer, 1987; Dekkers, de Laeter and Malone, 1991), namely, that, in a collection code structure such as that of upper secondary science in Western Australia, students' science choices tend to be highly sex-differentiated. The pattern of choice results, as in the example shown here, in the numerical predominance of girls in the biological sciences and boys in the physical sciences.

Clearly, in Western Australia, this pattern does not come about because of any differential in girls' and boys' previous science achievement, since as demonstrated earlier in this chapter, their achievement at the end of Year 10 has been close to equal, or in girls' favour, for many years. Rather, it appears that the pattern tends to be associated with a host of other factors related to students' gender. The particular upper school curriculum and assessment structure into which students are thrust at Year 11, a structure typical in many ways of Bernstein's collection code, allows these gender-related factors to manifest themselves and moreover, contributes to an image of the physical sciences as somewhat exclusive of females.

In summary, in terms of students' participation in science, it would appear that at upper secondary level curriculum structure in Western Australia during the years 1976–1993 was not a design conducive either to science-for-all or to gender equity in science. It is emphasised that this curriculum was a subject-centred curriculum, with strong classification and framing, associated with an external examination, a

Table 7.1

Western Australia 1976-1993: Numbers of females and males in Year 12 cohort and numbers of males and females enrolled in five upper secondary school science subjects

Year	Population					
	All Year 12 students		<i>Biology</i>		<i>Chemistry</i>	
	Male	Female	Male	Female	Male	Female
1976	N/A	N/A	1967	2700	1789	676
1977	N/A	N/A	1758	2732	1805	774
1978	N/A	N/A	1711	2915	1750	921
1979	N/A	N/A	1674	2906	1915	960
1980	3174	3986	1742	2767	1795	1081
1981	3717	4126	1502	2415	1834	1039
1982	3670	4002	1417	2153	1882	1107
1983	4196	4250	1538	2183	2021	1242
1984	4525	4574	1670	2307	2041	1256
1985	5000	5046	1818	2460	2193	1399
1986	5514	5807	1542	1757	1995	1172
1987	6125	6345	1508	1736	2067	1304
1988	6534	7111	1440	1544	2243	1458
1989	6612	7145	1266	1575	2169	1493
1990	6272	7198	1130	1596	2225	1495
1991	7052	7821	1271	1658	2288	1741
1992	7615	8118	1228	1648	2424	1823
1993			1062	1454	2445	1976

Year	Population					
	<i>Human Biology</i>		<i>Physical Science</i>		<i>Physics</i>	
	Male	Female	Male	Female	Male	Female
1976	681	1827	N/A	N/A	1910	584
1977	735	2144	N/A	N/A	1901	594
1978	666	2120	N/A	N/A	1813	723
1979	649	2102	162	118	1888	718
1980	588	2102	230	186	1854	760
1981	633	2383	276	257	1898	763
1982	681	2299	283	293	1931	850
1983	779	2572	317	332	2167	938
1984	1010	2969	348	295	2152	980
1985	1248	3249	435	336	2345	1067
1986	1291	3654	453	347	2180	878
1987	1387	3824	486	357	2210	891
1988	1674	4440	439	322	2391	932
1989	1586	4297	441	318	2360	996
1990	1476	4268	345	298	2229	889
1991	1981	4708	387	226	2331	993
1992	1920	4584	343	262	2320	968
1993	1830	4226	279	301	2353	969

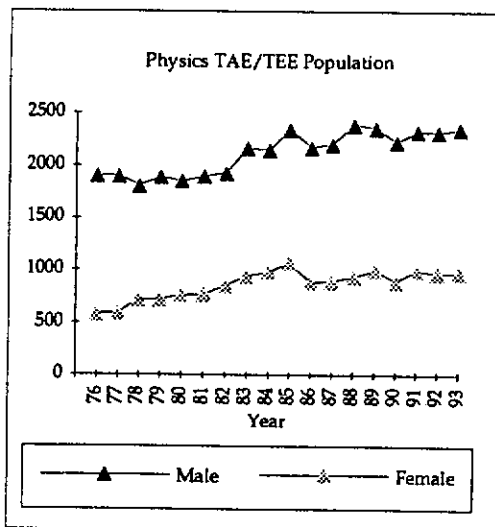
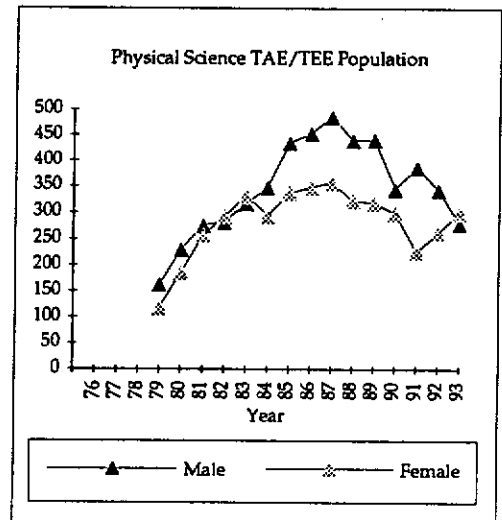
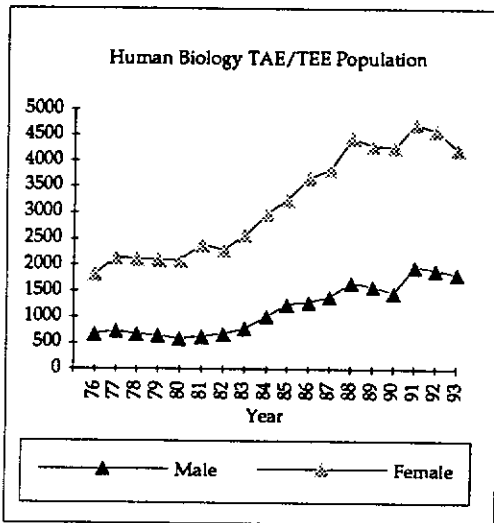
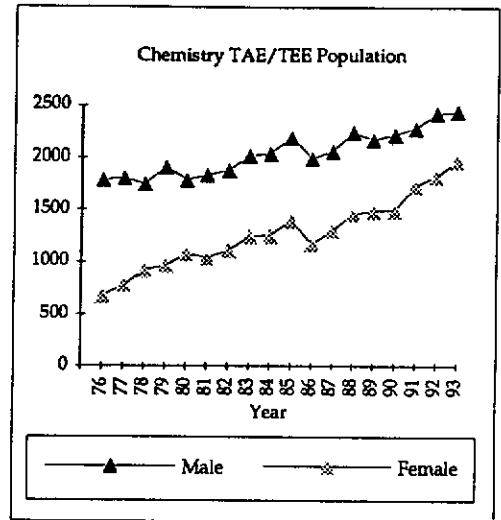
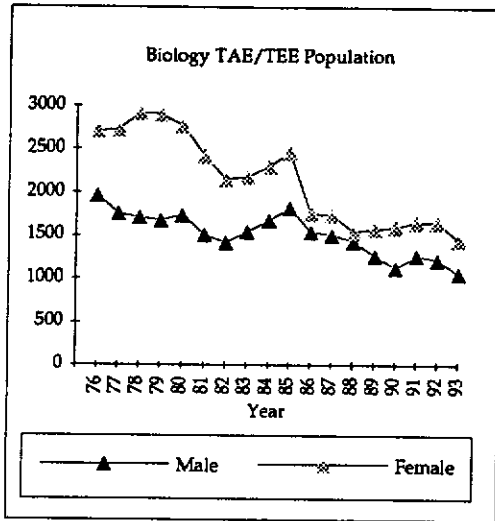


Figure 7.3. Western Australia 1976-1993: Numbers of females and males enrolled in five upper secondary school science subjects.

containment policy as described by Fensham (1985) and freedom of subject choice for students. Again, as in the case of the Unit Curriculum, it appears that the more strongly a curriculum inclines towards the collection code, the stronger the sex-differentiation of students' science choices, and the stronger the association of males with the physical sciences and with Bernstein's collection code, and females with the biological sciences and Bernstein's integrated code.

It is of interest, however, to note some apparent exceptions to this general pattern, in the cases of *Geology* and *Senior Science*. *Geology* is a subject with strong classification and framing. Yet, as demonstrated by Coates (1994), it is not perceived as a high status subject and only very small numbers of students enrol in it. (Most of these students are male and are not drawn from the high achievers in science.) Further, the reason *Geology* does not attract students is that it does not lead anywhere of value to the students – it is not defined as prerequisite study for further education or employment (even in the field of geology). In this context, *Senior Science* also is interesting. It is an integrated code subject and, as might be expected from the Bernstein/Young theories, attracts relatively few students. However, as shown in Figure 7.2, its enrolments increased substantially in 1993, an increase which took place in association with changes to TAFE entry conditions to include acceptance of *Senior Science*. Thus, whether a subject is linked to students' anticipated future studies or employment appears also to be a criterion for a collection code subject.

Enrolment is, however, only one dimension of student involvement with science. In this study it was of interest also to examine the relative achievement of males and females in this system, especially given the equal or slightly superior achievement of females compared to males at lower secondary level during many of the years covered by this

study. As indicated earlier, students' scores in the State-wide TAE/TEE were used to investigate patterns of achievement.

Achievement in Upper Secondary School Science, 1976–1993

The Measure of Achievement: The External Examination

During the period investigated in this study (1976–1993) the external examination in all TAE/TEE science subjects essentially was a three-hour, written examination paper [Western Australia. Board of Secondary Education (1977–1984). *Tertiary Admissions Examination (TAE) Papers, Biology, Chemistry, Human Biology, Physics, Physical Science*; Western Australia. Secondary Education Authority (1985–1993). *Tertiary Entrance Examination (TEE) Examination Papers, Biology, Chemistry, Human Biology, Physics, Physical Science*.] The examination papers were set by an Examining Panel consisting of three members – two from the tertiary sector and one from the secondary sector [Western Australia. Secondary Education Authority (1985–1993), Minutes, Tertiary Entrance Subject Committee]. The vast majority of members of Examining Panels were male.

Although there was some variation across years and across subjects, the typical examination paper contained multiple-choice questions (between 20 and 45 percent of the total), and essay questions (never more than 20 percent of the total) with the remainder made up of short answer questions. In the physical sciences, most questions reflected a strongly algorithmic view of science. In the early years of the TAE, a small proportion of the total assessment in science subjects (typically 10 percent) was based on records of students' practical work. In *Human Biology*, this proportion was higher than in other science subjects (20 percent) and was based on a major project, usually on a socially relevant topic. In general, the procedures for obtaining this practical or project

mark in science subjects were somewhat cumbersome and the practical or project requirement was abandoned in the later years of the TAE and was never a direct part of the external mark for the TEE.

Officially, the external examination was based on the syllabus statement for the course. However, inspection of the Syllabus Manuals over the years (Western Australia. Board of Secondary Education, 1977–1984; Western Australia. Secondary Education Authority, 1985–1993), demonstrates that many of these statements, especially in the years prior to 1988, essentially were lists of topics to be covered. They left a considerable amount of room for interpretation and for examiners to impose, through the examination, their particular vision of what was important in a subject. In this context, it is cause for concern that the majority of Examining Panel members are male. As indicated by Fowler (1993), an analysis of mathematics examination papers in Victoria over a number of years revealed a bias towards problems which drew on male culture and experiences, a bias which appeared to increase in association with all-male examiners. It is possible that this has also occurred in Western Australia.

The relatively loose structure of the syllabus statements also is cause for concern in other ways. There is strong anecdotal evidence that the predictability of certain examiners was acknowledged widely and, when Examining Panels changed membership, there was always a certain amount of anxiety about the nature of the next examination paper. There was some concern that, where loosely structured syllabus statements existed, they left considerable room for examiners to fall into what Andrich (1989) has called the two traps of test construction – to attempt to differentiate amongst students by first, making the assessment involve "a substantial component of speed" and second, "including questions which are related only tangentially to the syllabus" (p. 82) questions which,

because they draw on experience and knowledge gained outside the classroom setting, may well advantage the highly educationally resourced students.

There also is a considerable amount of evidence that, at least during the period of upper secondary education focused on in this study (the years 1976–1993), the syllabus, the pedagogy and the school-based assessment procedures in all of the examinable science subjects were dominated by the content and style of the external examination. Evidence cited already in Chapter 6, in relation to the introduction of the new subject *Physical Science* in 1978, indicated teachers' overwhelming concern to know, from the outset of their teaching in Year 11, the precise nature of the examination paper their students would be confronted with in Year 12. For teachers, although the course had specified objectives, it was the examination which determined the knowledge of most value. More wide-ranging evidence of this phenomenon, however, comes from scrutiny of the minutes of the various science subject Syllabus Committees [Western Australia. Secondary Education Authority (1985–1990). Minutes, Syllabus committees for *Biology, Chemistry, Human Biology, Physics, Physical Science*] especially in March–April of each year, following the release of the previous year's examiners' reports for each subject. The minutes for all subjects reveal, consistently, the general concern of members to ensure that the syllabus statement complied with the needs and priorities identified by examiners. As discussed previously in Chapter 4, the external examination was the means by which knowledge was legitimated. It also was an important symbol of the high status of a subject, and there are many examples, over the years, of attempts to increase the status and credibility (and *inter alia* the popularity) of non-examinable subjects by linking them to the external examination system (see Andrich, 1989).

Overall Trends in Achievement, based on the External Examination

To investigate sex differences in achievement, an effect size was calculated, for each subject in each year, based on students' scores in the State-wide TAE/TEE. Table 7.2 and Figure 7.6 show the trends of effect sizes in relation to males' and females' TAE/TEE Raw Scores in the five examinable science subjects between 1976 and 1993.

Table 7.2

Western Australia, 1976–1993: Gender effect sizes (E/S) of TAE/TEE Raw Scores in five upper secondary school science subjects

Year	Subject				
	<i>Biology</i>	<i>Chemistry</i>	<i>Human Biology</i>	<i>Physical Science</i>	<i>Physics</i>
	RAW E/S	RAW E/S	RAW E/S	RAW E/S	RAW E/S
1976	-0.07	0.04	-0.52	N/A	0.10
1977	-0.10	0.05	-0.53	N/A	0.22
1978	-0.04	0.00	-0.42	N/A	0.36
1979	-0.04	0.08	-0.21	-0.19	0.19
1980	-0.07	-0.06	-0.47	-0.36	-0.07
1981	-0.01	0.06	-0.29	-0.29	0.04
1982	-0.02	0.09	-0.31	-0.29	0.13
1983	-0.05	0.12	-0.28	-0.11	0.26
1984	-0.05	0.10	-0.24	-0.45	0.13
1985	-0.01	0.08	-0.12	-0.37	0.10
1986	-0.19	0.04	-0.16	-0.28	0.10
1987	-0.07	0.06	-0.13	-0.26	-0.03
1988	-0.07	-0.01	-0.06	-0.24	-0.04
1989	-0.18	0.10	-0.06	-0.16	0.10
1990	-0.04	0.22	-0.14	-0.38	0.12
1991	-0.11	0.05	-0.05	-0.27	0.03
1992	-0.04	0.16	-0.12	-0.30	0.08
1993	-0.03	0.06	-0.14	-0.31	0.06

It can be seen that most effect sizes were less than the accepted 0.2 level of practical significance and thus, considered individually, would be termed trivial. Their general trend, however, was in a direction consistent with findings concerning sex differences in achievement in science subjects elsewhere in the world (as reported in Chapters 1 and 4 of

this thesis). In the more integrated code subjects (*Biology, Human Biology and Physical Science*) nearly all effect sizes were negative (i.e. in females' favour). In the collection code physical science subjects, *Chemistry and Physics*, effect sizes in nearly all years were positive (i.e. in males' favour), but rarely at a level of practical significance. More specifically,

- in *Biology*, although all effect sizes were in females' favour, none exceeded 0.2 in magnitude;
- in *Human Biology*, all effect sizes were in females' favour and prior to 1985 exceeded 0.2 in magnitude (in some years quite considerably); in the year 1977 the effect size would have been termed moderate (in the range 0.5–0.8) rather than the small (0.2–0.5); after 1985 the effect sizes in *Human Biology* reduced progressively and continued to stay within the non-significant range;
- in *Physical Science*, in most years since this subject was first examined (1979) the effect size in females' favour exceeded 0.2 in magnitude;
- in *Physics*, the effect size in males' favour was significant only in the years 1977, 1978 and 1983; in 1980, 1987 and 1988 the effect sizes, although less than 0.2, were in females' favour;
- in *Chemistry*, 1990 was the only year in which the effect size in males' favour reached the level of practical significance; as was the case in *Physics*, 1980 and 1988 were years when the effect size in *Chemistry* was in females' favour;

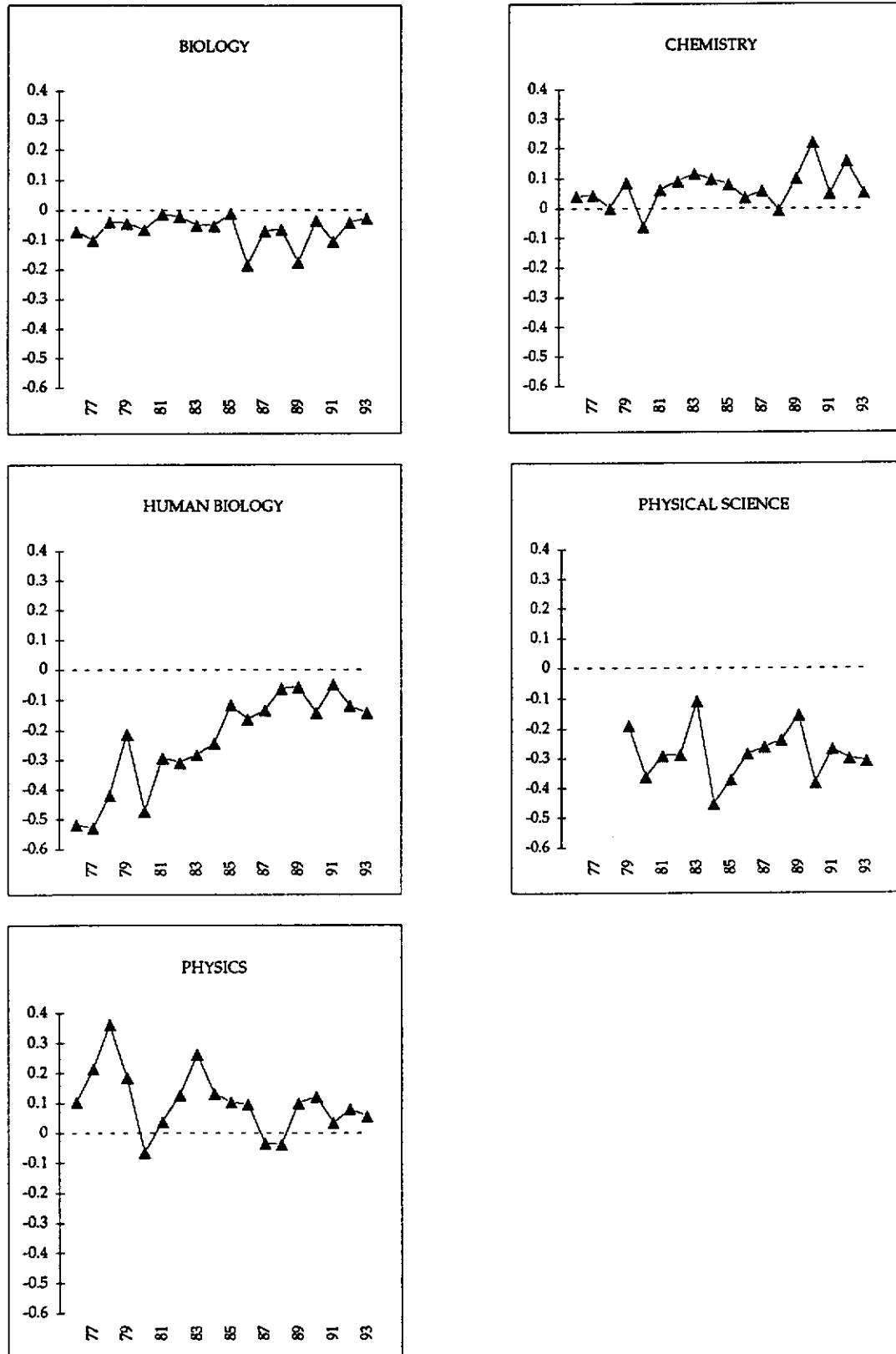


Figure 7.4. Western Australia, 1976–1993: Gender effect sizes of TAE/TEE Raw Scores in five upper secondary school science subjects.

These findings are of interest in several ways. First, although, as reported earlier in this chapter, at least since 1980, females' achievement in science at lower secondary school level has been equal to or higher than that of males, at upper secondary school level, this situation was only found consistently in the more integrated code subjects (*Biology, Human Biology* and *Physical Science*). In the collection code physical science subjects, *Chemistry* and *Physics*, males almost always did better in the external examination. Given the small proportion of females in *Physics* and *Chemistry*, this achievement difference is likely to be due to the higher proportion of able females in *Biology, Human Biology* and *Physical Science*. However, it is nevertheless worthy of further investigation in terms of gender code theory, as reported in Chapter 8. Second, in the early years of *Human Biology*, when the mark for the subject contained a significant component based on the project, girls' achievement was significantly higher than that of boys, but in the later years, when the project was abandoned, the sex difference in achievement reduced considerably. This finding suggests, again, an association between gender and mode of assessment, as encapsulated in the gender code model.

SUMMARY

The findings to this point lend support to the gender code theory regarding the selection and transmission of school science knowledge. At the level of the overall lower secondary school curriculum structure, in comparison with the integrated code Achievement Certificate structure, the more collection code Unit Curriculum, with the increased choice it required of students, was associated with strong gender stereotyping of

science enrolments. Similarly, the disjunction at the choice point at end of Year 10, when students were confronted with a strong collection code curriculum, was also associated with increased gender stereotyping of students' choices. Further, the high measured science achievement of females in the school-assessed lower secondary school system in Western Australia (higher in fact than that of males) contrasts with the finding, elsewhere in the world, on standardised tests of science achievement, of higher achievement by males than females in science. This suggests support for the aspects of gender coding associated with Broadfoot's typology of formal/informal modes of assessment.

The findings point again to the central significance of gender in the distribution of science knowledge. With respect to achievement, this analysis has demonstrated also that the gender code may be operating in relation to achievement of males and females in science. Further evidence, presented in the next chapter, highlights additional aspects of gender coding associated with another change in the upper secondary school science curriculum in 1986. In particular, the evidence lends additional support to the dimension of the gender code theory concerned with Broadfoot's formal and informal modes of assessment.

Chapter 8

GENDER CODE THEORY AND UPPER SECONDARY SCIENCE 1986-1993: A SOCIO-HISTORICAL PERSPECTIVE

INTRODUCTION

This chapter takes up the theme of the gender coding of school science in the context of the major changes to upper secondary school curriculum and assessment which were implemented in Western Australia in 1985–1986. It continues to explore links between structural changes and the gender code, in this case with a particular focus on aspects of gender coding associated with Broadfoot's (1969) typology of different modes of assessment. The chapter has two major sections. The first section focuses on the specific curriculum change and analyses its consequences in terms of gender code theory. The second section discusses a number of issues which arose during the period of the change, linking these issues to the gender code model and, more specifically, to concerns about curriculum legitimacy and rigour.

THE STRUCTURE OF UPPER SECONDARY CURRICULUM AND ASSESSMENT, 1986–1993

The 1985–1986 Changes

In 1984, the Western Australian State Government accepted the recommendations of the McGaw Report produced by the Working Party on School Certification and Tertiary Admissions Procedures chaired by

Professor Barry McGaw. As a consequence, major changes to upper secondary school curriculum and assessment were implemented in 1985 and impacted on Year 12 and on certification and tertiary entrance procedures for the first time in 1986. The major catalyst for the changes, which has been outlined already in Chapters 1 and 6 and demonstrated graphically in Figure 7.2, was the increasing retention of students into upper secondary schooling, the resultant changes in the characteristics of the upper secondary school cohort, and a situation in which most students were continuing to study a program consisting of six TAE subjects, even students whose abilities and aspirations were not suited to such a program. Other catalysts for the changes also were important to this present study, for example, the perceived difference in status between TAE and CSE-General subjects and the fact that admission to a tertiary institution was based, almost exclusively, on the aggregate of a student's scaled examination results in six TAE subjects, with little use being made of school-based assessments. Indeed, both of these latter two catalysts were at the heart of issues which were fundamental to the study reported in this thesis.

In the above context, the stated intention of the McGaw recommendations was "to free the upper secondary school from many of the constraints imposed by the requirements of tertiary institutions without sacrificing the quality of preparation for tertiary study" (Western Australia, 1984b, p. viii). The suite of courses accepted for tertiary entrance purposes [now called Tertiary Entrance Examination (TEE) subjects] was reduced in number from 33 to 20 (a number which was increased almost immediately to 25, as a result of intense lobbying of the Minister for Education by groups representative of *Art, Ancient History* and three small-enrolment Asian languages). Further, within the list of TEE subjects, some restrictions were introduced. First, the list was

divided into two groups – Quantitative/Science subjects, and Humanities/Social Science subjects; second, some combinations of subjects which had been allowable under the previous system were proscribed under the new system, because of overlap between the syllabus content of certain pairs of subjects (for example *Biology* and *Human Biology*, *Chemistry* and *Physical Science*, *Physics* and *Physical Science*). More flexibility, however, was introduced by the division of each of the formerly two-year upper secondary subjects into a separate Year 11 and Year 12 course, with the external examination [the name of which was changed to the Tertiary Entrance Examination (TEE)] based only on the Year 12 course.

At the same time, tertiary entrance requirements were changed in a number of highly significant ways. First, although incentives remained for all students to continue to study six subjects in each of Years 11 and 12, the aggregated score used for tertiary admissions purposes [known, in the new system, as the Tertiary Entrance Score (TES)] could now be based on as few as three TEE subjects instead of six as in the previous system, provided the subjects used in the calculation of the TES included at least one subject from each of the Quantitative/Science list and the Humanities/Social Science list. The reduction in number of subjects used for the aggregate was intended to allow students more freedom to include non-examinable (former CSE-General) subjects in their programs of study, and the restriction in terms of lists was intended to ensure breadth and balance in students' programs of study. Second, as referred to briefly in Chapter 3, changes were made to the score used for competitive tertiary entrance purposes. In the former system, it had been based entirely on the external examination. In the post-McGaw structure, this score (now called a student's "final score" or "Scaled Combined Score" in a TEE subject) was based on a scaled 50:50 composite of the student's

standardised TEE Raw Score and the student's school-based assessment, with the latter moderated by the former. Clearly, this second change increased the salience of continuous, school-based assessment in the whole system.

The Issue of Prerequisites

Concomitantly with the implementation of the McGaw recommendations, tertiary institutions in Western Australia changed their policies on prerequisites for tertiary studies. As noted in the McGaw report (Western Australia, 1984b, p. 59), prior to 1986, all tertiary institutions in Western Australia had official policies which declared no prerequisites for admission, although the successful completion of specific upper secondary subjects in preparation for some tertiary courses always was encouraged strongly. In the post-McGaw system, however, the tertiary institutions made the prerequisites for some degree programs quite explicit. The institutions' new policies related, almost exclusively, to the specification of *Physics*, *Chemistry* and the TEE mathematics subjects for degree programs in engineering, mathematics and the sciences. Interestingly, degree programs in the biological sciences, as well as in the physical sciences, tended to specify *Physics* and *Chemistry* as prerequisites. No prerequisites, however, were specified for degree programs in the humanities areas. The result of this was that, if students selected programs of study which included *Physics*, *Chemistry* and *Mathematics II* and *III*, they had more tertiary level options open to them than if they selected programs which did not include these subjects.

Interpretation of the McGaw Changes in Terms of Gender Code Theory

In terms of the theoretical framework developed in this thesis, the McGaw-inspired changes left much of the collection code nature of the

upper secondary curriculum intact. The curriculum as a whole remained subject-centred and strongly classified, with strong boundaries between subjects. The shift towards increased choice for students, as argued earlier in this thesis, actually increased the collection code orientation. Further, the imposition of restrictions which required students to include subjects from both the Humanities/Social Science list and the Quantitative/Science list of TEE subjects added another dimension of strong classification to the curriculum, based, in this case, on boundaries between groups of subjects. This distinction between different groups of subjects was emphasised further by the action of the tertiary institutions to define prerequisites. In fact, these specified prerequisites were such that they not only reinforced the collection code orientation of the curriculum, but also reinforced the mathematics/physical science hegemony, identified by Collins (1989) and discussed in Chapters 2 and 5 of this thesis.

At the same time, however, there was one dimension of the McGaw changes which represented a shift towards an integrated code curriculum. This dimension related to the weaker framing of the new curriculum/assessment structure, because of the increased salience of school-based assessment. Even this, however, was mitigated to some extent by the continuing important role of the external examination in statistical moderation of school-based assessment. Thus, the external examination, a feature of strong framing and the collection code, continued to play a significant part in the post-McGaw system.

Given this situation, it is of interest to analyse the post-McGaw changes in terms of their implications for the relationship between gender and science. From the gender code theory developed in this thesis, it would be predicted that, first, under the stronger classification of the post-McGaw structure, the enrolments of females would shift

towards the more integrated code subjects (resulting in fewer females in the physical sciences and more in the biological sciences) and, second, that the overall shift to a more weakly framed assessment structure would enhance the achievement of females. Given the focus of the initial theoretical frameworks of Bernstein, Young and Broadfoot on class-related issues, it is of interest also to explore the extent to which any gender coding of student subject enrolment and achievement interacts with students' ability and socioeconomic status.

THE POST-MCGAW UPPER SECONDARY CURRICULUM

Overall Participation in the Initial Years (1986–1987)

In the years immediately following the implementation of the McGaw recommendations, there was considerable interest in students' patterns of upper secondary school subject choice. A study carried out at the Secondary Education Authority (Parker, 1986) found that the choices of post-McGaw students differed considerably from those of pre-McGaw students. Typically, the latter had engaged mainly in the study of TAE subjects, with the majority of students (around 70 percent) selecting six TAE subjects and no CSE-General subjects. In Bernstein/Young terms, such a program of study would be seen as having a strong collection code orientation. In the post-McGaw years, however, only 26 percent of students chose a 6 TEE/0 non-TEE subject combination, while 5/1, 4/2 and 3/3 combinations were chosen by 27, 22 and 10 percent of students respectively. Again, in Bernstein/Young terms, these combinations would be seen as progressive movement towards an integrated code. However, although the SEA study indicated that the post-McGaw students were indeed taking advantage of the extra flexibility made

available by the new structure, it demonstrated also that the movement away from a 6 TEE/0 non-TEE subject combination was

- stronger for females than for males
- stronger for students in Government schools than non-Government schools
- stronger for students in rural schools than in metropolitan schools
- considerably stronger for students who had lower measured achievement levels.

Thus, the drift away from a collection code curriculum was stronger for students who, in Andrich's (1989) terms, would be seen as "poorly resourced" and, at the level of the total secondary school curriculum, the findings of the SEA study suggest a form of overarching and powerful gender coding of students' subject choices. While it is not the intention here to explore these findings in detail, it is clear that they provide important background to the immediate concerns of the gender coding of school science.

Participation in Science Subjects, 1986–1993

This section focuses in more detail on the years 1985–1993 with respect to the science subject enrolment trends shown previously in Figure 7.2. In this case,

- Figure 8.1 presents the enrolment data for 1985–1993 in column graph form, showing also the distribution of females and males in each science subject;
- Table 8.1 provides, for the purpose of comparisons, the male/female breakdown of the total Year 12 examination/certification population in each year 1985–1993. It then shows the group of males and the group of females in each

science subject as a percentage of the total group of males and females, respectively, in the relevant Year 12 cohort.

From Figure 8.1, it can be seen that, in the post-McGaw (post-1985) system, although *Biology*, *Human Biology*, *Chemistry* and *Physics* remained, as in previous years, the most popular upper secondary school science subjects, enrolments in all major science subjects except *Human Biology* decreased, in the case of *Biology* quite significantly. The reductions were especially dramatic in 1986, the first year of the implementation of the new system. In subsequent years, although there was some recovery in most subjects in terms of the absolute numbers of students enrolled, the numbers continued to represent a smaller proportion of the Year 12 examination population than had been the case prior to 1986. In the biological sciences, *Human Biology*, which, as pointed out in Chapter 2, is a slightly more integrated code subject than *Biology*, took over from *Biology* as the most popular science subject.

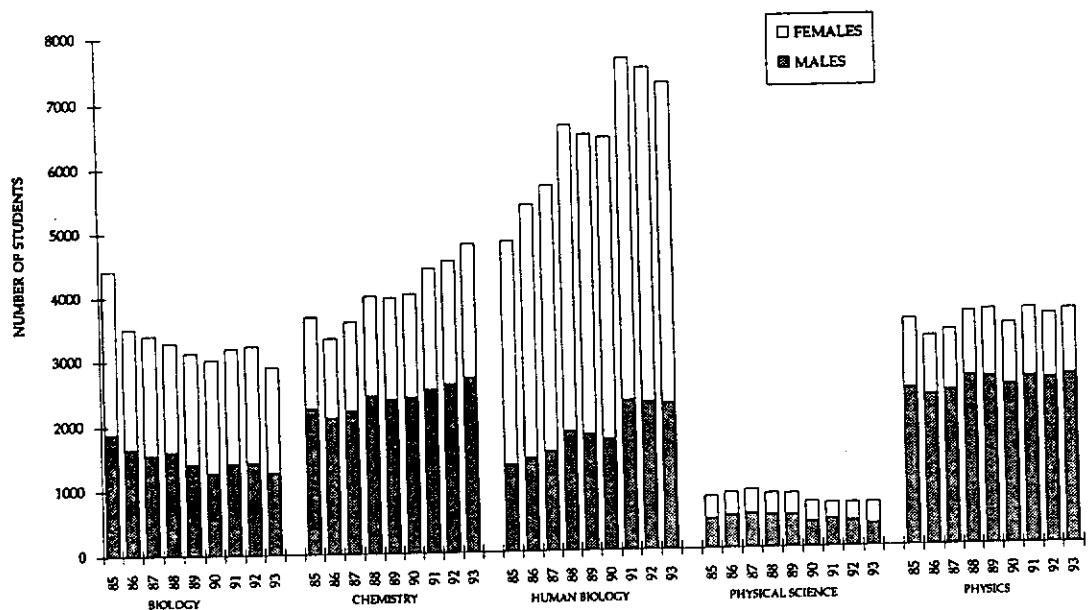


Figure 8.1. Western Australia, Year 12, 1985–1993: Science subject enrolments, showing percentage of male cohort and of female cohort in each subject.

Table 8.1

Western Australia, Year 12, 1985–1993: Number of males/females in the certification/examination population for each subject and percentage of the male/female cohort in each science subject

Year	Subject					
	All Year 12 students		<i>Biology</i>		<i>Chemistry</i>	
	Males	Females	Males	Females	Males	Females
1985	6417	7241	29.3	35.0	35.0	19.7
1986	6890	7900	23.8	23.6	30.5	15.5
1987	7397	8429	20.9	21.9	29.8	16.4
1988	8296	9410	19.2	17.9	29.2	16.6
1989	8407	9573	16.7	17.9	28.2	16.6
1990	8462	10120	14.9	17.3	28.4	15.9
1991	9580	10974	14.7	16.2	26.2	17.3
1992	9828	11064	14.4	16.3	26.3	17.5
1993	10065	11088	12.6	14.7	26.7	18.9

Year	Subject					
	<i>Human Biology</i>		<i>Physical Science</i>		<i>Physics</i>	
	Males	Females	Males	Females	Males	Females
1985	20.7	48.1	7.0	4.8	37.5	15.0
1986	20.7	50.0	7.1	4.6	33.5	11.5
1987	20.7	49.2	7.0	4.5	32.0	11.2
1988	22.1	50.7	6.0	3.6	31.1	10.8
1989	21.2	48.9	5.9	3.5	30.4	11.2
1990	20.1	46.5	4.5	3.1	28.7	9.5
1991	24.0	48.4	4.4	2.3	26.7	9.8
1992	23.1	46.9	4.0	2.5	25.6	9.2
1993	22.3	44.9	3.4	3.0	25.6	9.3

With respect to the gender coding of students' enrolments, it is clear from Table 8.1 that females, more than males, shifted from the collection code science subjects to the more integrated code science subjects. Contrasting the 1985–1986 data, it can be seen that, in *Physics* and *Chemistry*, the strong collection code subjects, the reduction in numbers was particularly marked for females. In *Physics*, the number of females declined from 15 percent of the total Year 12 female cohort in 1985 to 11.5 percent in 1986 (in terms of absolute numbers, from 1085 in

1985 to 909 in 1986, a drop of 16 percent). This compared with the male decline from 37.5 percent of the total Year 12 male cohort in 1985 to 33.5 percent in 1986 (in terms of absolute numbers, a drop of only 4 percent). Similarly in *Chemistry*, there was a 14 percent decline for females, compared to a 6 percent decline for males between 1985 and 1986.

Table 8.1 shows also that the decline in *Biology* numbers between 1985 and 1986 is due particularly to a reduction in the number of females enrolled, from 35 percent of the female cohort to 23.6 percent. In this regard, it is of interest that the analysis by Sydney-Smith and Offer (1991), referred to in Chapter 2, demonstrated that the post-McGaw system no longer provided, as the previous system had done, encouragement for students to study both biology subjects, and that this resulted in students not choosing *Biology*, which was perceived to be the more conceptually difficult of the two, or, in terms of the gender code, the subject with the more collection code orientation. Thus, the movement of females from *Biology* to *Human Biology* represents, again, a shift of females towards a more integrated code science subject.

Interactions of Gender Coding with Student

Ability and Socioeconomic Status

Analyses focused on the type of school (non-Government or Government) attended by students, and on an independent measure of students' "general ability" (scores on the ASAT) were used to investigate whether there was evidence of a possible interaction between gender, ability and socioeconomic status in students' participation in science. These analyses are discussed below.

Trends According to General "Ability"

For the purposes of this analysis, students' scores on the Australian Scholastic Aptitude Test (ASAT) provided the most accessible independent measure of their overall ability. The problems with using this measure were recognised, including, for example, the possible sex bias in the test (Adams, 1984), but it nevertheless was regarded as acceptable in this case, because first, it is a measure available for virtually every Year 12 student during the period of this study and, second, it is a measure based on a test of demonstrated reliability.

For this analysis, the total Year 12 population was divided into quartiles according to ASAT scores and the number of students from each ASAT quartile in each science subject then was determined. The results of this analysis are shown in Table 8.2 and Figure 8.2. (Students in the 1st quartile are those with the highest ASAT scores.)

Table 8.2 and Figure 8.2 indicate that the group enrolling in *Physics* and *Chemistry* contained a large proportion of highly able students, while those enrolling in the other science subjects were considerably less able. In addition, as shown in Table 8.3, effect sizes for ASAT in nearly all subjects in nearly all years were in females' favour. Thus the mean ASAT scores of the females in most subjects (but especially in *Physics*) were higher than those of the males. In other words, the group of females in *Physics* (and to some extent also in *Chemistry*), constituted an especially able group of females. As such and, given also females' higher achievement than males in science at lower secondary school level (as reported earlier in Chapter 7), the females in *Physics* and *Chemistry* might have been expected to achieve at least as well as, if not better than, the males. Whether this, in fact, was the case is discussed later in this chapter.

Table 8.2

Western Australia, Year 12, 1985–1993: Number of students in each ASAT "quartile" in the certification/examination population and percentage of each ASAT "quartile" in each science subject

Year	All				Subject <i>Biology</i>			
	1st	2nd	3rd	4th	1st	2nd	3rd	4th
1985	3205	3050	3302	2995	27.5	38.5	39.3	31.1
1986	3250	3279	3041	3227	23.4	30.4	27.0	23.2
1987	3583	3235	3680	3546	22.1	26.8	26.4	19.9
1988	3940	3576	4236	3853	18.2	22.1	21.1	18.2
1989	3926	4089	3740	3892	16.4	21.9	19.6	16.7
1990	3994	3629	4056	3903	17.7	20.0	19.6	15.6
1991	3629	4518	3991	4208	18.3	20.2	18.7	15.6
1992	4174	3818	4207	4170	17.7	21.0	19.0	14.6
1993	3830	3552	3939	3787	16.5	19.8	18.8	12.8

Year	<i>Chemistry</i>				<i>Human Biology</i>			
	1st	2nd	3rd	4th	1st	2nd	3rd	4th
1985	63.0	30.7	14.7	5.7	17.8	36.4	45.0	44.9
1986	56.9	25.9	11.9	5.1	22.1	37.4	47.1	48.8
1987	53.2	27.5	13.2	6.6	23.7	37.2	44.5	44.7
1988	53.4	26.0	14.2	6.9	21.3	40.1	47.3	49.1
1989	54.2	24.9	12.6	3.8	21.5	38.8	44.7	47.3
1990	52.4	25.7	15.0	7.6	23.3	38.3	43.9	45.7
1991	61.3	27.3	13.9	6.4	23.3	40.9	49.5	50.7
1992	54.5	29.1	16.3	8.0	23.8	39.8	47.4	50.3
1993	58.6	33.5	19.7	10.6	25.6	40.8	46.7	50.4

Year	<i>Physical Science</i>				<i>Physics</i>			
	1st	2nd	3rd	4th	1st	2nd	3rd	4th
1985	5.5	8.2	7.2	3.7	59.7	29.1	13.5	5.9
1986	4.9	8.1	6.5	5.7	55.3	24.4	11.4	5.3
1987	5.2	8.2	6.7	4.8	49.8	24.4	12.6	5.8
1988	4.6	6.0	5.7	4.0	49.9	22.8	12.1	5.6
1989	3.4	6.0	5.8	4.9	49.3	21.8	12.6	5.7
1990	2.8	5.2	4.7	4.3	45.6	19.9	12.5	6.8
1991	2.9	4.7	4.2	3.3	52.2	20.9	11.2	5.4
1992	2.8	4.5	4.7	3.4	44.3	20.7	12.8	5.8
1993	2.7	4.3	4.9	4.3	46.1	22.7	14.4	8.0

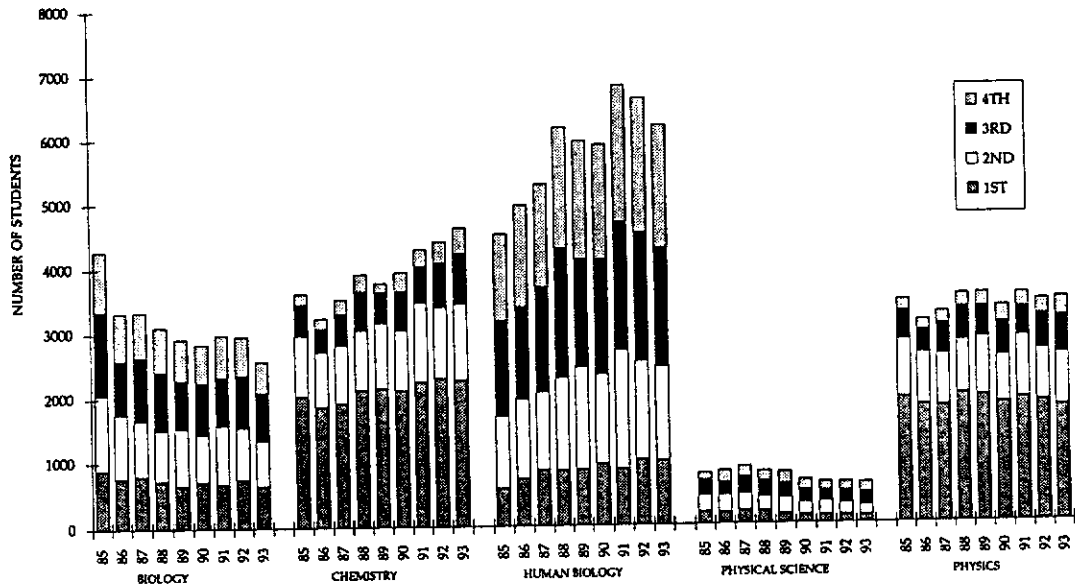


Figure 8.2. Western Australia, Year 12, 1985–1993: Science subject enrolments, showing percentage of each ASAT quartile in each subject.

Table 8.3

Western Australia 1986-1993: Effect sizes of ASAT scores of the groups of males and females in five upper secondary school science subjects

Subject	Year							
	1986	1987	1988	1989	1990	1991	1992	1993
<i>Biology</i>	-0.10	-0.03	-0.02	-0.10	-0.06	-0.02	-0.02	-0.14
<i>Chemistry</i>	-0.21	-0.15	-0.07	-0.11	0.09	0.08	0.10	-0.05
<i>Human Biology</i>	0.01	0.01	0.06	0.02	0.01	0.03	0.04	-0.01
<i>Physical Science</i>	-0.25	-0.43	-0.34	-0.21	-0.33	-0.18	-0.17	-0.39
<i>Physics</i>	-0.25	-0.16	-0.14	-0.14	-0.21	-0.09	-0.09	-0.23

As in the former case of the data differentiated according to student sex, these ability-differentiated data highlight some issues of concern. On

the one hand, as indicated earlier, between 20 and 30 percent of students, including a high proportion of low ability and, in Andrich's terms, poorly educationally resourced students, study no science at all. On the other hand, as shown in Figures 8.2 and 8.3, of those who do study science, an academically elite, predominantly male group tends to take *Physics* and *Chemistry*, while the others opt for the biological sciences. Thus, *Human Biology*, and/or *Biology* become a kind of de facto science-for-all. However, in almost all cases, students studying science in the collection code upper secondary curriculum operating in Western Australia are experiencing only half the scientific world. As noted by Fensham (1985, p. 425), students in this kind of curriculum structure are confined to a "very limited view of the rich field we know as sciences" . Further, this situation contributes to the perpetuation of an image of the physical sciences as both academically elite and somewhat exclusive of females.

Trends According to Type of School Attended by Students

The differentiation of the enrolment data according to the type of school (Government or non-Government) attended by students adds yet another important dimension to this analysis. Although, as indicated by Ministry of Education data on the levels of "disadvantage" of schools in Western Australia (Western Australia. Ministry of Education, 1992) there are many students from families of high socio-economic status attending Government schools in Western Australia, the proportion in non-Government schools is much greater. Thus, effectively, differentiation of the science enrolment data according to type of school provides an approximate measure of the socio-economic status of the students in each subject. This analysis is shown in Table 8.4 and Figure 8.3.

Table 8.4

Western Australia, Year 12, 1985–1993: Number of students in Government/non-Government schools in the certification/examination population and percentage of the Government/non-Government student cohorts in each science subject

Year	Subject					
	All Year 12 students		<i>Biology</i>		<i>Chemistry</i>	
	Govt	Non Govt	Govt	Non Govt	Govt	Non Govt
1985	9286	4373	31.8	33.4	26.0	28.8
1986	10816	3960	20.5	32.3	20.1	29.2
1987	11540	4283	19.8	28.1	20.1	29.4
1988	12533	5173	16.7	22.9	19.6	29.6
1989	12650	5330	15.8	21.0	19.7	27.5
1990	12871	5891	14.3	19.9	19.2	26.1
1991	14464	6090	13.5	20.3	19.0	27.2
1992	14714	6178	13.8	19.2	18.5	29.2
1993	14534	6619	12.5	16.3	20.0	28.2

Year	Subject					
	<i>Human Biology</i>		<i>Physical Science</i>		<i>Physics</i>	
	Govt	Non Govt	Govt	Non Govt	Govt	Non Govt
1985	38.5	28.3	7.1	3.1	25.2	26.4
1986	36.2	37.0	6.2	4.6	19.4	28.4
1987	35.7	36.4	6.6	3.1	19.0	26.1
1988	37.8	36.1	5.4	3.0	18.0	25.9
1989	35.9	35.9	5.6	2.2	18.1	25.0
1990	32.9	36.8	4.1	2.8	16.1	22.4
1991	36.8	37.4	4.0	1.5	15.5	22.8
1992	35.5	36.3	3.8	1.9	14.7	22.3
1993	32.8	37.2	3.8	1.9	15.1	21.3

The analysis indicates that the enrolments in the more collection code science subjects tend, proportionately, to be considerably higher in non-Government schools than they are in Government schools. Further, in relation to the initial impact of the McGaw recommendations in 1985–1986, Table 8.4 and Figure 8.3 demonstrate a large decline in enrolment of Government school students in the collection code sciences (*Physics* and *Chemistry*) but an increase in enrolment of non-Government school students in these subjects. However, in the years after 1986, although *Chemistry* enrolments in both types of school

remained stable, *Physics* enrolments in both types of school declined. When considered together with the previous analysis according to sex of student, this pattern suggests a possible gender-class interaction in relation to enrolment in collection code/ integrated code subjects.

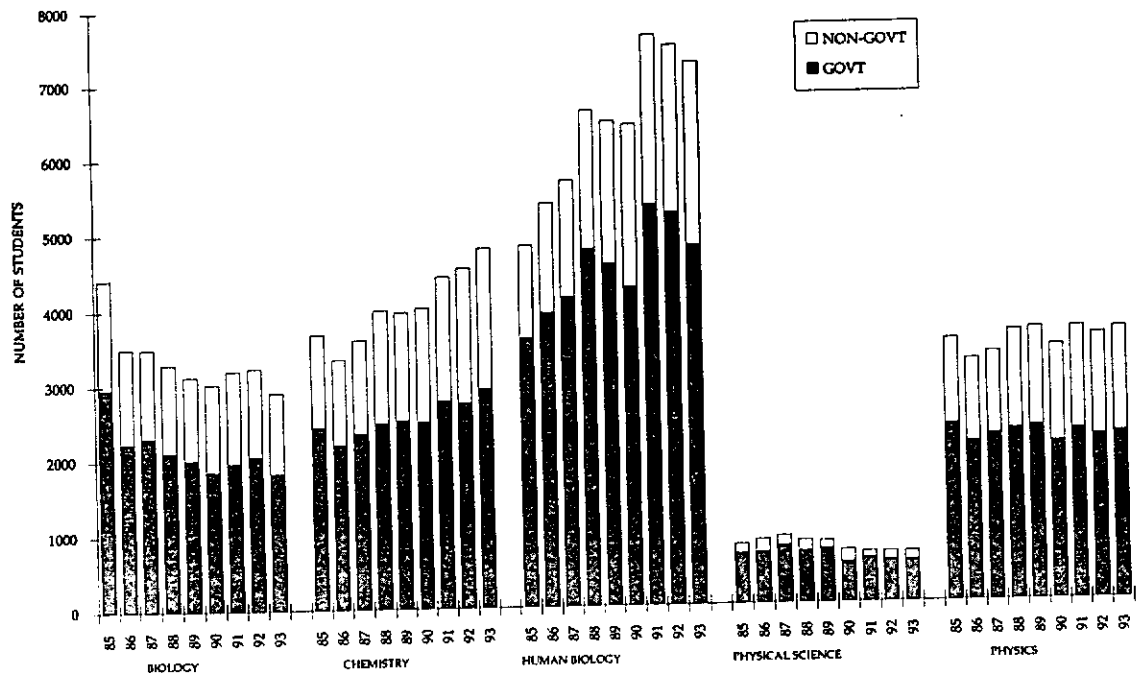


Figure 8.3. Western Australia, Year 12, 1985–1993: Science subject enrolments, showing percentage of students from Government/ non-Government schools in each subject

Summary

The apparent effects of the McGaw changes on enrolment of students in the major science subjects, differentiated according to the three variables (sex, ability and socioeconomic status of students) can be summarised as follows:

- In *Biology*, students who were female, of middle ability (i.e. from the second top ASAT Quartile) and from Government schools,

accounted, in the main, for the 1985–1986 drop in numbers. The further decline in numbers since 1986 appears to be associated mainly with a decreased number of male enrolments.

- In *Chemistry*, following the initial 1985–1986 drop, which involved mainly a reduction in the proportion of students of middle ability and, to a lesser extent, females, the enrolments increased steadily until 1988, stabilised for three years, then underwent further increases in 1991–1993. Particular increases occurred in the proportion of females, and in the proportion of students from the lowest quartile of the ASAT distribution and from non-Government schools. (It should be noted that the latter phenomenon is probably associated with the increased number of non-English speaking (full fee-paying, overseas) students in Western Australia in recent years, and the relatively low ASAT scores obtained by these students, even those of quite high ability in science or mathematics.)
- In *Human Biology*, the relatively steady increase in enrolments over the years, peaking in 1991, has been remarkable. The expansion has occurred fairly evenly in terms of the three variables displayed in Figures 8.1–8.3, with perhaps a slight increase in the proportion of females, non-Government school students and students from the top ASAT quartile. It is of interest that when the increase in *Human Biology* enrolments is viewed in the context of the decrease in *Biology* enrolments, it can be seen that, although the balance between the two subjects has shifted, the total number of students studying a biological science at Year 12 level has remained very much the same.
- In *Physics*, as in *Chemistry*, the 1985–1986 reduction involved mainly females and middle ability students. Enrolments in

Physics, however, have not recovered to quite the same extent as those in *Chemistry* in the years 1987-90. The proportion of females has remained relatively low. Further, for reasons as explained above for *Chemistry*, the population has shifted towards a greater proportion of students from non-Government schools and students from the lowest ASAT quartile.

Overall, this analysis shows that the collection code appears to operate in a somewhat exclusive manner, a manner which reinforces the privileged access of high socio-economic groups and males to the physical sciences, and rationalises this elite on the basis of "ability". The State-wide data presented earlier in the chapter, however, tend to challenge this "ability"-based rationale. The accumulated evidence suggests that, irrespective of demonstrated prior achievement, females, especially females of low socio-economic status, tend to enrol in integrated code science subjects while males, especially those of high socio-economic status, tend to enrol in collection code science subjects. This finding provides a clear demonstration of Andrich's (1989) concept of the success of highly resourced students in a fast track secondary school system such as that in Western Australia.

In the post-McGaw system, the trends in *Biology* enrolments are especially interesting from the theoretical perspective of this thesis. Given that the large drop in enrolments in 1986 clearly is attributable mainly to females in Government schools and, given also the analysis of Sydney-Smith and Offer (1991), it can only be concluded that females of lower socio-economic status, more than other students in the cohort, were deterred from selecting *Biology*, because of its reputed and perceived conceptual difficulty. This confirms the trend reported in Chapter 6 in relation to *Physical Science*, namely, that if a subject is perceived to be more difficult (and is accorded, therefore, higher status), it

is considered to be more suitable for males than females and more suitable for students of higher rather than lower socioeconomic status.

These findings confirm the gender coding of the upper secondary science curriculum in Western Australia. They suggest also, as might be predicted from the earlier research of Young and Bernstein, an additional effect associated with students' socio-economic status. In this case, science curricula or science subjects which have the attributes of Bernstein's collection code appear to be associated not only with maleness, but also with high socio-economic status. And conversely, subjects more characteristic of Bernstein's integrated code appear to be associated not only with femaleness, but also with low socio-economic status.

Achievement in Science Subjects 1986–1993

As indicated earlier, after 1986, for each Tertiary Entrance Examination (TEE) subject, measures of student performance were available from both the external examination (namely, a TEE Raw Score out of 100) and a combination of school-based and external assessment (namely, the "final score" or "Scaled Combined Score", a scaled 50:50 composite of the statistically moderated school assessment and the standardised TEE score). Table 8.5 and Figure 8.4 present, for each science subject for each of the years 1986–1993, the comparisons between the effect sizes for these Scaled Combined Scores and the effect sizes for Raw Scores (repeating, in the latter case, some of the figures presented previously in Table 7.2 and Figure 7.4).

The comparisons in Table 8.5 and Figure 8.4 reveal a systematic effect, over the whole eight years shown in the analysis. Almost without exception, the effect sizes for the Scaled Combined Scores were more towards the negative (i.e. more in females' favour) than those for the Raw Scores. The shift was quite small in absolute size and, only in a few

instances, did it turn a non-significant difference into one of more practical significance (e.g. *Biology* in 1986 and 1989, *Human Biology* in 1986 and 1987, *Physical Science* in 1989 all became significant in females' favour). Similarly, in only one case (*Chemistry* in 1990) did it reduce a significant difference (formerly in males' favour) to a non-significant one. In the context of these shifts, it is important to note that they were not an outcome of the scaling procedure: as shown elsewhere (Parker, 1992b) effect sizes for Scaled (uncombined) Scores and those for Raw Scores are almost identical. The shift appears to be due to the contribution of the school-based score to the final Scaled Combined Score.

Table 8.5

Western Australia 1986-1993: Gender effect sizes of TEE Raw Scores (RAW) and Scaled Combined Scores (SCS) in five upper secondary school science subjects

Year	Subject									
	<i>Biology</i>		<i>Chemistry</i>		<i>Human Biology</i>		<i>Physical Science</i>		<i>Physics</i>	
	RAW	SCS	RAW	SCS	RAW	SCS	RAW	SCS	RAW	SCS
1986	-0.19	-0.23	0.04	0.01	-0.16	-0.22	-0.28	-0.35	0.10	0.04
1987	-0.07	-0.13	0.06	0.07	-0.13	-0.20	-0.26	-0.33	-0.03	-0.04
1988	-0.07	-0.14	-0.01	-0.04	-0.06	-0.12	-0.24	-0.30	-0.04	-0.08
1989	-0.18	-0.24	0.10	0.08	-0.06	-0.09	-0.16	-0.23	0.10	0.04
1990	-0.04	-0.07	0.22	0.15	-0.14	-0.15	-0.38	-0.38	0.12	0.04
1991	-0.11	-0.15	0.05	0.03	-0.05	-0.09	-0.27	-0.32	0.03	-0.01
1992	-0.04	-0.10	0.16	0.12	-0.12	-0.15	-0.30	-0.38	0.08	0.04
1993	-0.03	-0.09	0.06	0.02	-0.14	-0.18	-0.31	-0.33	0.06	-0.01

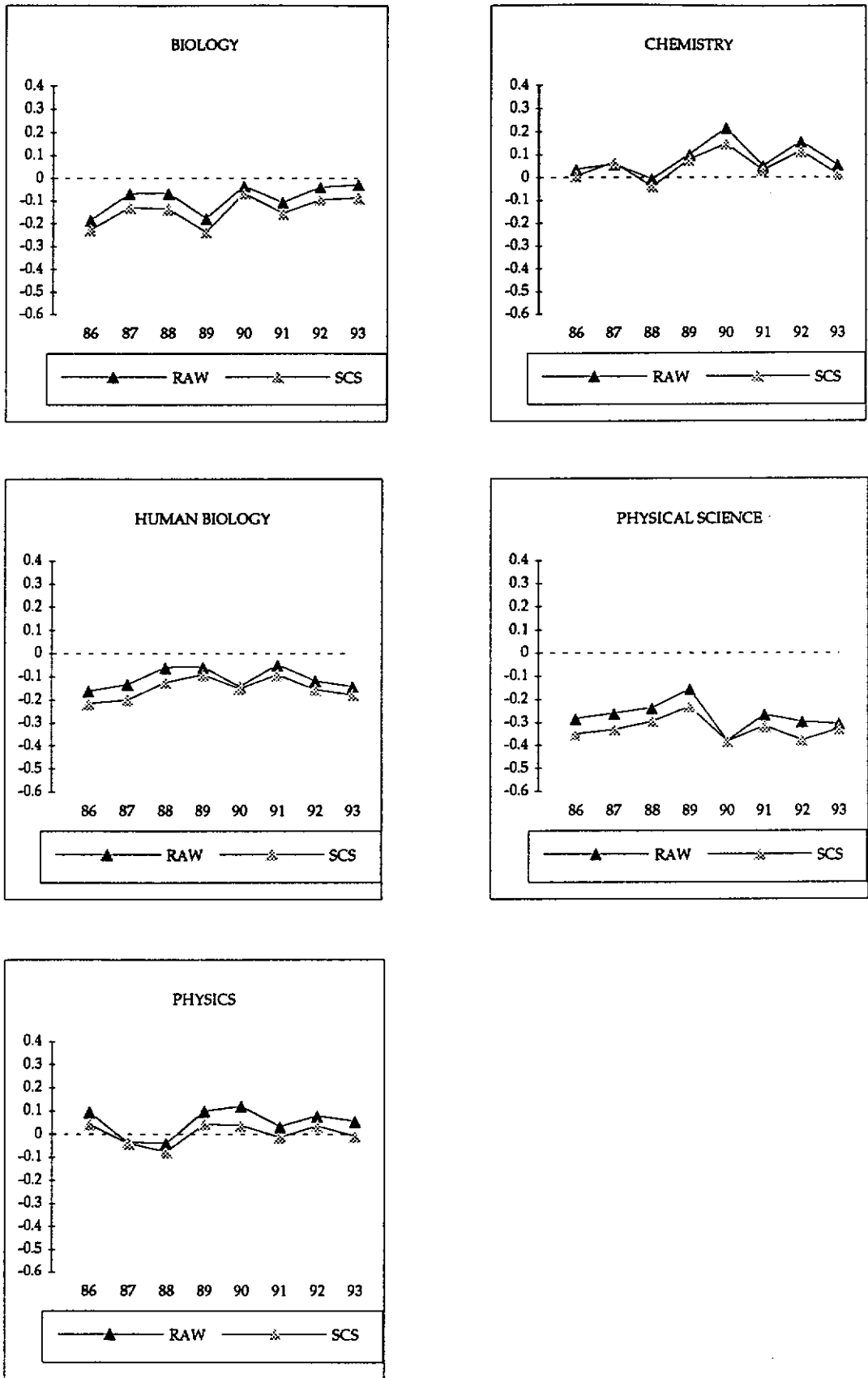


Figure 8.4. Western Australia 1986-1993: Graphical comparison of trends in gender effect sizes of TEE Raw Scores (RAW) and Scaled Combined Scores (SCS) in five upper secondary school science subjects.

In summary, this analysis of student achievement under two different assessment structures in science subjects in Western Australia has revealed that, systematically, over an extended period, the external examinations in science subjects in Western Australia appear to have favoured males, while school-based assessment appears to have favoured females. Thus, the analysis has confirmed the prediction made earlier, on the basis of the gender code theory. It also has validated aspects of the gender code theory associated with Broadfoot's typology of formal and informal assessment modes.

In this study, the differences in gender effect size under the two different modes of assessment (totally external examination compared with assessment containing a significant component of school-based assessment) were relatively small in most years and, in relation to individual subjects, tended to be of little practical significance. However, evidence from other analyses (Parker & Tims, 1993) indicates that the same trend exists in other TEE subjects, such as mathematics. Thus, if scores from several subjects are aggregated, as they are in Western Australia to produce a Tertiary Entrance Score (TES) for each student, any systematic bias such as that identified here also aggregates. In the pre-McGaw years (1976–1985), in which such aggregation was carried out solely on the basis of students' examination scores, it appears that there might have been a bias against females in the compilation of the TES. To some extent this bias has been removed by the procedures adopted since 1986, which prescribe the inclusion of a school-based assessment. Whether, however, the post-1985 procedures have accounted fully for the former bias against females remains questionable, and is the subject of further investigations.

THE MCGAW CHANGES FROM A SOCIOLOGY OF KNOWLEDGE PERSPECTIVE

The Assumption of Neutrality of Modes of Assessment

During and even subsequent to the period of the McGaw changes, the merits or otherwise of external and school-based assessment had been debated vigorously, both in Western Australia and elsewhere. Generally, as exemplified in the McGaw report (Western Australia, 1984b) the debates focused on

- "course coverage" and "sampling of student performance" issues (i.e. limited coverage by an examination, compared with substantial coverage, over a considerable period of time, by school-based assessment);
- a "student anxiety" issue (seen as operating more in relation to examinations than school-based assessment);
- a "perceived objectivity" issue (seen as operating in favour of external examinations)
- a "comparability" issue (seen as problematic in school-based assessment, but eliminated by external examinations) and
- the "administrative convenience" issue (seen as operating in favour of external examinations)

Issues related to social justice did not surface in the debates. For example, at the time that the McGaw Working Party was deliberating, some research evidence from the UK was available, suggesting an interaction between gender and mode of assessment (Forrest, 1971, 1972; Linn, 1973; Nuttall, Backhouse & Willmott, 1974; Willmott, 1977, as cited in Chapter 4 of this thesis). This evidence does not appear to have been taken into account, however, and although the reasons for this omission are a matter of conjecture, it is perhaps significant that the McGaw

Working Party consisted entirely of men. Of its 12 members, six were senior academics, four were senior educational administrators from the school systems, and the remaining two were from the State-wide statutory bodies concerned with upper secondary education (the then Board of Secondary Education and the Tertiary Institutions Service Centre). Interestingly, in the context of this study, nine of the 12 had a strong background in either science or science education. Typically, it would be expected that they were deeply committed to Collins' (1989) "positivist hegemony" and to modernist assumptions about the virtues of traditional forms of assessment.

The Comparability Issue

With the increased salience of school-based assessment in the post-McGaw system, the issue of comparability of school-based assessments became more important. As indicated in Chapter 1, school-based assessment had, since 1976, contributed to the grade in each subject which appeared on a student's Certificate of Secondary Education (CSE). Further, the way a final score was derived in the post-McGaw system was only marginally different from the way a CSE grade had been derived in the former system. However, the CSE had been part of a standards-referenced system, with the certificate available to all who met the predetermined standards. Hence the former CSE grades had never had very much significance as criteria for selection into employment or further study. By contrast, and as emphasised by Andrich (1989), under the post-McGaw system, school-based assessment became part of a competitive, norm-referenced system, linked to the selection of students by tertiary institutions. Thus only when, following the McGaw changes, the inclusion of school-based assessment became a significant part of the selection process, did both the education community and the general

public begin to take it seriously and to demand much stricter comparability of school-based assessments.

To some extent, the retention of the external examination was seen as helping to overcome the problem of comparability. Both educators and the general public were comfortable with the perceived "rigour" the external examination added to the system (Western Australia. Secondary Education Authority. Minutes, SEA Meeting, June, 1986). In addition, however, each subject Syllabus Committee was required to develop an Assessment Structure to serve as a mandatory guide to school-based assessment.

Assessment Structures in Science Subjects

In each Year 12 science course, as in all courses accredited by the Secondary Education Authority, the Assessment Structure was stated to be an integral part of the course. The structure specified the components and learning outcomes to be included in the assessment program for the course, the weighting to be applied to these components and the types of assessment considered appropriate for the course. Typically, the structures were arrived at following extensive discussion within Syllabus Committees. Following this, the structures needed to be approved by the Authority's Tertiary Entrance Subject Committee and by the Authority itself. Minutes of all of these groups reveal an overriding concern for the Assessment Structures to ensure rigour for the TEE subjects, usually through a strong emphasis on traditional tests and examinations. Considerable concern tended to be expressed about the validity of marks given for assignments undertaken outside of the classroom. In particular, the assessment of co-operative group work, on a group rather than an individualistic basis, was discouraged, because it was deemed to be too open to collusion or cheating. Also, there was strong resistance to

the allocation of marks for learning outcomes that were specifically attitudinal in nature.

Thus, as seen from the SEA Syllabus Manuals (1986–1993), the major characteristics of the Assessment Structures for all TEE science subjects were as follows:

- In relation to learning outcomes, they tended to be weighted heavily (typically between 80 and 90%) towards readily quantifiable outcomes in cognitive and process objectives. Even in courses where a strong emphasis on attitudinal objectives was specified in the syllabus statement (e.g. *Human Biology* and *Physical Science*), no allocation was made for achievement of objectives in the affective domain.
- In relation to types of assessment, they tended to be weighted heavily (generally around 80%) towards examinations and topic tests. The weighting for practical work hovered around 10-15%. Other assigned work was allocated a very low weighting (typically 0-5%)

In terms of gender code theory, there clearly was considerable pressure to ensure that, in the interests of rigour and legitimacy, school-based assessment remained as formal and strongly framed as possible.

The Definition of a TEE Subject

As implied earlier in this chapter, the aftermath of the McGaw report was marked by controversy regarding the list of TEE subjects. There was considerable debate about the attributes of a TEE subject and about the reasons why some subjects were included in the list of TEE subjects and others were not. Although no science subjects were deleted in the McGaw-recommended reduction of the list from 33 to 20, the debate surrounding the efforts of the proponents of some of the 13

deleted subjects to have their subjects reinstated on the list is relevant to the concerns of this study. The debate culminated in the development, by the Secondary Education Authority, of the following list of nine criteria defining a TEE subject:

- (a) A TEE subject should provide a preparation for tertiary study.
 - (b) The scaling population in a TEE subjects should be sufficiently large for scaling to be reliable.
 - (c) Restrictions should apply to subjects with a significant overlap (e.g. *Biology/Human Biology, Mathematics I/Mathematics II/III, Physical Science/Physics or Chemistry*).
 - (d) The balance between humanities/social studies and quantitative/science subjects should allow a reasonable degree of choice by all students, and should not advantage/disadvantage students with particular talents.
 - (e) A TEE subject must be amenable to reliable and valid assessment.
 - (f) Becoming a TEE subject should not distort the intrinsic nature of the subject area to the detriment of either the subject or the group of students typically attracted to that subject.
 - (g) The list of TEE subjects must be kept within reasonable limits in terms of the Authority's budget.
 - (h) A TEE subject must be appropriate in terms of its educational content.
 - (i) Addition to the TEE subject list will be considered in relation to the total package for tertiary admission, including the 3,4,5 subject Tertiary Entrance Score.
- (Western Australia. Secondary Education Authority. 1988)

Arguably, the above list was serving multiple purposes. It appears to have no consistent theoretical underpinning, although the theories of Bernstein and Young or even of less radical philosophers could have provided such a basis. Of all the criteria, only (a) and (h) relate to the substantive content of the subject, emphasising the "preparation for

tertiary studies" issue so important in a fast track system. Of the other criteria, three could be seen as educational. First, criterion (c), while partly also relating to fairness and equity, appears to be an attempt to ensure sufficient variety in students' programs of study and to stop students "double-dipping"; second, criterion (d) is attempting to ensure that the list caters fairly for all students; and, third, criterion (f), while partly epistemological in origin, is attempting to guarantee the fundamental validity and educational soundness of the subjects offered to students.

Of the remaining criteria, criterion (g) is patently operational in its rationale, criterion (b) is partly operational and partly concerned with fairness and validity, and criterion (e) relates to the legitimating function of the TEE and caters to the belief, referred to earlier in this thesis, that legitimacy and credibility hinge on an external examination. Finally, criterion (i) is difficult to place – it appears to be acknowledging the complexities of the competitive system and, at the same time, providing those with control over the TEE list with a mechanism for weighing up virtually any subject and finding an excuse to exclude it. In this context, it is of interest to note that the fact that some of the existing subjects on the TEE list did not conform to the above criteria was not lost on the educational community at large.

In the context of the theoretical basis of this study, the attempt to define a TEE subject is of particular interest. In essence, it constituted an attempt to define the collection code and, in essence, what emerged is close to a tautological definition. It is, moreover, a salutary reminder of Mannheim's (1936) arguments about ideologies, explained in Chapter 1. It will be recalled that Mannheim made three major points about ideologies: first, that, as in the case of the definition of a TEE subject, it is almost impossible to establish their validity by empirical means; second,

that, again as in the case of TEE subjects in Western Australia, they arise in specific social settings; and third, that ideologies tend, like success in TEE subjects in Western Australia, to provide positive support for particular ways of life for specific groups in the community. Thus, in Mannheim's terms, the attributes of a TEE subject are not definable, because the subject is part of a whole ideology – a set of beliefs and ideas that have arisen in a specific socio-cultural setting and which serve to confirm and legitimate the existing power relations in that setting. In this sense the vagueness and tautological nature of the criteria are hardly surprising. The criteria and the way they are operationalised are, indeed, part of a "code". If the code is too explicit, then it is no longer useful for the purposes of legitimating power relations.

Ongoing Concerns regarding Rigour

Both in the education community and in the wider community, many reactions to the McGaw-inspired changes focused on a perception that the changes had led to decreased rigour in students' upper secondary programmes of study, partly as a consequence of the reduction in the mandatory number of TEE subjects students needed to study and partly because of the decreased emphasis on examinations. These reductions also were seen to have implications for the degree to which students were prepared well for tertiary studies and implications for the viability of some TEE subjects in terms of student enrolments. In 1988, the expression of concerns about the post-McGaw system, particularly in relation to rigour of students' studies and comparability of assessment between schools, reached a crescendo in the committees of the Secondary Education Authority. The concerns drew a response from the political level when Professor David Andrich was commissioned by the Minister for Education to undertake a review of the situation.

The report by Andrich (1989), which addressed the issue of rigour systematically, was particularly helpful to this study. Andrich defined rigour in terms of three related components, which he termed "experience" (described as the anchoring of learning "in experience and direct involvement in the topic or activity"); "representation" (which he saw as involving "*representation and a level of abstraction of a body of knowledge, often circumscribed as a discipline area*"); and, "reflection", [which he explained was present if a subject involves "*reflection, (which) goes beyond having traditional experiences and understanding traditional representations, to reflecting and even questioning those experiences and representations*"] (pp. 19-20).

To a large extent, the relationship between rigour and TEE subjects is, again, largely tautological; as Andrich (1989) has noted, "the greater rigour of the TEE subjects exists more or less by definition" (p. 32). It is of interest, however, to analyse the collection code TEE science subjects in terms of Andrich's definition of rigour. As he himself pointed out, the perceived rigour of the TEE subjects rests mainly on the representational component of his definition.

The Representational Component of Rigour in TEE Subjects

"Representation", in Andrich's definition of rigour, relates to the dimension of knowing commonly called "theory". It contrasts with and balances the practical emphasis of his experiential component of rigour. TEE science subjects, particularly in the physical sciences, are characterised by the manipulation of symbols of one kind or another, symbols which permit "understanding and knowledge to transcend specific experiences" (p. 20). In other words, they are represented in a way which anchors them in the abstract, generalised view of knowledge associated with a perception of "difficulty" and, as shown in the case of *Physical Science* in

Western Australia in Chapter 6, with Young's definition of high status knowledge.

The Reflective Component of Rigour in TEE Subjects

In TEE science subjects, the "reflective" component of Andrich's model of rigour is rather less in evidence than the representational component. For example, in the 1990 Syllabus Manual there is no evidence of this component in the *Chemistry* syllabus statement (pp. 321-325). Similarly, in *Physics*, although the stated general aim of the course is "to provide an understanding of the natural world and give the background necessary for further study in physics", there is little evidence of "reflection" in the syllabus statement (pp. 345-356). It consists of lists related to "content objectives" (for all of which the operative verb is "to know"), "process objectives" (all at a relatively unsophisticated level of drawing clear diagrams or presenting experimental data) and "psychomotor skill objectives" (involving the setting up and use of equipment).

The more integrated code science subjects, however, show some evidence of reflection. In *Biology*, one of the aims is to help students to develop "ability to apply biological understanding to appropriate problems (including those of everyday life) and to approach those problems in rational ways" (pp. 313, 314). In *Physical Science* one aim is to produce students who can demonstrate their competence in "using their knowledge and critical appraisal of available information to solve scientific problems and to make reasoned judgments" (p. 337). Similarly, in *Human Biology*, one of the general aims is to foster positive attitudes towards, amongst other things, "the scientific study of human problems and a willingness to adopt rational scientific approaches to solving these problems" (p. 333), although, as pointed out earlier, this affective

dimension of the course is not part of its mandatory Assessment Structure.

The Experiential Component of Rigour in TEE Subjects

In general, at the level of science subject Syllabus statements, the experiential component of rigour tends to fare rather better than the reflective component. All syllabus statements for TEE science subjects have a significant emphasis on practical work. The translation of this emphasis into reality, however, appears to be problematic in some cases. In the Assessment Structures for some TEE science subjects (for example *Chemistry* and *Human Biology*), the allocation of marks for practical work (in term of what is called "laboratory performance") is as low as 5 percent. As indicated earlier in this thesis (particularly in Chapter 2), the highest status amongst school science subjects tends to be accorded to those subjects which reflect a view of science as somewhat disembodied theory. The Western Australian *Physics* syllabus, in particular, has evolved as one centred on routine, decontextualised algorithms, rather than on students' direct practical involvement with a topic or activity. By contrast, however, the less strongly classified science subjects *Biology*, *Human Biology* and *Physical Science*, which are centred rather more on experiential learning, are viewed generally as lower status and easier subjects. In this context, it is relevant that, drawing on examples of professions such as medicine and engineering, Andrich (1989, p. 20) argued against the more traditional views that practical experience and manual activity actually preclude rigour (and high status) in an area of study. In fact, he defined practical experiences as fundamental to that rigour.

Other Implications of the Andrich Review of the McGaw Implementation

While the report by Andrich (1989) goes beyond the immediate concerns of this thesis, two outcomes of the Andrich review are especially important in the context of gender code theory. The first of these is his recommendation that non-TEE subjects have an external assessment associated with them. Although this recommendation was not implemented, it reinforces the association between external examination and the perceived legitimacy/credibility of a subject. The second is his recommendation that the minimum number of subjects which could be used for determining a student's TES should be 4 rather than 3. This latter recommendation, in terms of the theory developed in this study, gave students slightly less choice in determining their upper secondary programs of study and thus, constituted a slightly less strongly classified curriculum structure.

Again, in the context of this study, it was of interest to explore this change in curriculum structure in terms of its effect on participation and achievement in school science. The implementation of the Andrich recommendations impacted on Year 12 students for the first time in 1992. Considered in terms of the gender code theory, it would be predicted that, because the classification of the post-Andrich curriculum was weaker, females would shift towards the collection code subjects (e.g. *Chemistry* and *Physics*) and away from the integrated code subjects (e.g. *Biology* and *Human Biology*). Inspection of Table 8.1 reveals that although very little movement took place in this regard in the 1992 enrolments, the prediction was confirmed, to some extent, by the shifts which took place in the 1993 enrolments. In *Chemistry*, the number of females rose from 17.5 percent of the female cohort to 18.9 percent and, conversely, in

respectively, from 16.3 and 46.9 percent to 14.7 and 44.9 percent. In *Physics* the enrolments remained relatively stable.

Clearly, these movements need to be interpreted with extreme caution at this stage. A trend cannot be established with data from only two years. However, the direction of these shifts is of interest in terms of the gender code theory and is worth monitoring in the future. To be sure, the decrease in the strength of classification of the post-Andrich upper secondary curriculum was a very small decrease, attributable only to the slightly decreased freedom of subject choice. The example of the Unit Curriculum in Chapter 7, however, demonstrated the sensitivity of the system in this regard.

SUMMARY

This chapter began with a description of the major upper secondary school curriculum changes initiated by the McGaw Report (Western Australia, 1984b). It was pointed out that, in terms of gender code theory, the post-McGaw curriculum and assessment structure was characterised by stronger classification but weaker framing than its predecessor. The chapter went on to predict the direction of changes in enrolment and achievement in science subjects under the post-McGaw structure, with reference to the three variables of sex, socio-economic status and general ability. It presented a test of these predictions based on an analysis of State-wide data. The analysis confirmed the predictions, suggesting a possible interaction between gender and class in relation to the gender code model. In particular, the analysis demonstrated that the gender effect sizes under two different modes of assessment (one totally external and the other a mixture of external and school-based) were in the direction

consistent with the assessment dimension of the gender code, as derived initially from Broadfoot (1979).

In the second section of the chapter, it was argued that definitions of high status subjects and of rigour essentially are tautological, and appear to be part of a whole ideology, with characteristics such as those defined by Mannheim (1936) (and discussed in Chapter 1 of this thesis). The arguments were presented in a discussion of the issues surrounding the McGaw changes which focused on

- the absence of a social justice perspective from the deliberations of the McGaw Committee;
- the major concerns which arose regarding rigour in the post-McGaw system, concerns which were addressed by an increasing reliance on strongly framed assessment, enforced through the external examination and through the inclusion of mandatory Assessment Structures for the school-based assessment of all subjects in the system;
- the tautological, rather confused definition of high status knowledge (represented as a "Tertiary Entrance Examination" (TEE) subject in the post-McGaw system);
- an analysis of rigour in Western Australian upper secondary school science subjects, based on the definition of rigour developed by Andrich (1989).

Finally, a discussion, again from the perspective of gender code theory, focused on some additional curriculum changes implemented to address the perceived "problems" of legitimacy and rigour which arose as a consequence of the first set of changes. In the next and final chapter, which draws together the theoretical and practical concerns addressed in this study, it is seen that the issues of legitimacy and rigour are linked, in

an integral way, to the concept of the gender code and the operationalisation of a gender-inclusive science curriculum.

Chapter 9

CONCLUSION: GENDER, CODES AND CONTROL

INTRODUCTION

This final chapter presents a summary of the whole study and a synthesis of its outcomes. The chapter is in two parts. The first part begins with a brief outline of the focus and purpose of the study. Following this, the theory-building phase (described in Chapters 2, 4 and 5) is summarised, culminating in a statement of the gender code hypothesis, represented diagrammatically in Figure 9.1. A synopsis of Chapters 6–8 then is presented, summarising the phase of the study in which the gender code theory was tested through a socio-historical analysis. It is argued that, although some disconfirming evidence was identified, the findings of the socio-historical analysis generally provided strong support for the gender code theory, especially in relation to the systematic gender effect of different modes of assessment.

The second part of the chapter focuses on methodological decisions taken as part of the study. The focus here is personal, reflecting the intensely personal nature of this study, as described earlier in Chapter 3. Each methodological decision is discussed and, as part of the discussion, issues concerning validity, generalisability, limitations and implications of the study are addressed.

THE FOCUS AND PURPOSE OF THE STUDY

This study focused on the relationship between gender and science. The perspective taken was that this relationship continues to be problematic, because of its dysfunctional consequences for science and for human beings. In addition, it was argued that the relationship is in need of further theoretically informed clarification, building on a synthesis of previous research originating from a variety of paradigms. Thus, the overall purpose of this study was to advance understanding of the gender/science relationship through the development and testing of a theory. Secondary school science, an area in which the problematic gender/science relationship is of particular concern and an area which suffers particularly acutely from lack of theory in this regard, was selected as the specific focus of this study.

The introductory chapter of this thesis presented a review of recent history of educational policy and practice related to sex-differentiated patterns of participation and achievement in secondary school science. The world-wide concern about these patterns was emphasised, as was the need to explore them systematically, from a perspective which allows for the questioning of taken-for-granted assumptions about knowledge. Thus, the sociology of knowledge, a discipline concerned essentially with the ideological basis of knowledge, provided the theoretical underpinnings for the study. From within this paradigm, it was argued, and subsequently demonstrated, that a synthesis of curriculum theory and feminist theory, especially when integrated also with the findings of empirical

research on school science and gender, provides fertile ground for the development of a theory about the gender/science relationship at school level. Thus, as stated in Chapter 1, the problem central to the study concerned the manner in which the structure of curriculum and assessment in secondary schools appears to influence the relationship between gender and science. In addressing this problem, the objectives of the study were as follows:

- (1) To develop a theory which integrates (i) theories about the sociology of knowledge developed by curriculum theorists, (ii) a literature review of empirical research concerning the manner in which science curriculum and assessment policy and practice appear to interact with gender and, (iii) theories developed from a postmodernist feminist perspective on scientific knowledge;
- (2) To test this theory through a socio-historical analysis of patterns of sex differences in participation and achievement in secondary school science in one Australian State, namely Western Australia.

Methodologically, this study was conducted in two phases, as described in Chapter 3, mirroring the two objectives of theory-building and theory-testing. Each of these phases involved a number of methodological decisions, which are discussed and evaluated, from a personal perspective, later in this chapter. For the present, the following synopses of Chapters 2, 4 and 5 and of Chapters 6–8 summarise the study with respect to the achievement, respectively, of its first and second objectives.

SYNOPSIS OF CHAPTERS 2, 4 AND 5: THE DEVELOPMENT OF THE GENDER CODE THEORY

The Initial Theoretical Framework

The initial theoretical framework for this study was developed from research emanating from the "new" sociology of education, including especially the work of Bernstein (1971a, 1971b, 1974, 1975, 1982, 1990) and Young (1971a, 1971b, 1973, 1974, 1975, 1976, 1977). During the past two decades this work has been described variously as inspirational, difficult, complex, incoherent and saturated with jargon. There is no doubt, however, about its influence on modern sociological thought (see, for example, Danzig, 1991) and there is an increasing consensus that its full potential has not yet been realised (Davies, 1994). In this regard, part of the value of the study reported in this thesis lies in its reinterpretation and elaboration of some of the rather abstract and convoluted writings of Bernstein and Young and the application of the elaborated theoretical framework to a particular problem.

In this study, the theorising of Bernstein and Young in relation to the attributes, selection, distribution and assessment of different forms of school knowledge was reviewed and critiqued. Bernstein's concepts of the "classification" and "framing" of knowledge into a "collection code" and an "integrated code", based on three "message systems" (namely, "curriculum", "pedagogy" and "evaluation") was combined with Young's concept of the status differentiation of knowledge according to its degree of "literacy", "individualism", "abstractness" and "unrelatedness". The combined Bernstein/Young theories were represented diagrammatically in the grid/group format shown in Figure 2.3. In addition, the seven upper secondary school science subjects in

Western Australia were positioned within Figure 2.3, based on evidence drawn mainly from their official syllabus statements.

As positioned in the Bernstein/Young reconceptualised framework (Figure 2.3), the physical science subjects *Physics* and *Chemistry* are collection code, high status knowledge, characterised by strong classification and strong framing. With respect to their strong classification, such subjects

- are relatively pure single disciplines, with clear distinct boundaries around them, requiring students to choose their studies quite deliberately,
- have strong boundary-maintaining devices (such as Syllabus Committees consisting of acknowledged experts in the area),
- have curriculum content which is abstract, highly dependent on written work and unrelated to non-school knowledge,
- tend to eschew the affective domain, concentrating mainly on cognitive outcomes,
- have content connected directly and explicitly to studies in higher education,

and, with respect to their strong framing, they have

- strong systemic control over the organisation, pacing and timing associated with the "transmission" of knowledge,
- asymmetrical teacher/pupil relationships (with power over pedagogy lying mainly in the hands of the teacher)
- pedagogy which tends to be formal, detached and unconnected to everyday, community processes,
- strongly individualistic pedagogy and assessment, based a great deal on "objective" written work.

Conversely, the biological science subjects, especially *Human Biology*, emerge as much closer to integrated code subjects. The subject called *Senior Science* emerges as the most integrated code of all the Western Australian upper secondary science subjects, characterised by exceptionally weak classification and framing. Described in terms derived from Bernstein and Young, the weak classification of such subjects is evidenced by

- multidisciplinary curriculum content, with knowledge from different areas presented in an integrated form, thus not requiring students to choose their studies, in any deliberate fashion, from different areas of knowledge,
- the absence of powerful boundary-maintaining devices (such as a Syllabus Committee),
- concrete, applied curriculum content, emphasising the qualitative rather than the quantitative,
- an explicit emphasis on the affective domain,
- a lack of direct connection to further or higher education,

and their weak framing is evidenced by

- teacher/pupil control over the organisation, pacing and timing associated with the teaching and learning of the subject,
- symmetrical teacher/pupil relationships (with both teacher and pupils able to exercise choice in relation to pedagogy),
- pedagogy which tends to be informal, responsive to the needs, motivations and attitudes of the pupils and linked to everyday, community processes,
- inclusion of oral presentation and group activity in the pedagogy and assessment.

A review of research on the stratification of school knowledge confirmed, essentially, the basic tenets of the combined Bernstein/Young framework. It illustrated that the categorisation of knowledge into clearly defined subjects and the subsequent hierarchical positioning of these subjects, are fundamental, in both a practical and an ideological sense, to the selective distribution of the knowledge within schools. Thus, in general terms, it was argued that education systems, through the stratification of knowledge, convert social hierarchies into academic hierarchies. The argument was based on research conducted by a wide range of researchers from many different countries [including Goodson (1983, 1985, 1990) and Hargreaves (1989) writing about the UK situation; Apple (1978, 1979, 1982) and Larabee (1986) from the US perspective; Tomkins (1986) from Canada; and, Bourdieu (1976) from France]. In a more specific sense, it was emphasised that the work of Collins (1989), in terms very similar to Young's, helps to highlight the placement and importance of the "positivist heartland" of the Australian academic curriculum ["mathematics, taught as the language of positivism, and physics and chemistry, taught as the most theoretical and cut-and-dried sciences" (Collins, 1989, p. 16)].

At this stage, certain weaknesses in the Bernstein/Young theories were identified. Some of these related to the lack of direct empirical support for the theories, even in relation to their fundamental premise defining class-based hierarchies as the major outcome of the codification of knowledge in the school curriculum. Two major weaknesses in relation to the present study, however, were first, that none of the work of Bernstein, Young or those who immediately followed them explored adequately the "message system" of "evaluation" and, second, that this work contains almost no reference to sex-related divisions of educational knowledge or to gender-based hierarchies.

In the sense that evaluation (termed "assessment" in this study) plays a key role in determining access to Collins' positivist heartland and, at the same time, legitimating that heartland, it was imperative to gain a better understanding of its role. The research of Broadfoot (1980, 1984, 1986, 1990, 1993) on the relationship between assessment, schools and society proved invaluable in this regard, especially her dynamic model, demonstrating a continuum from formal, externally set and marked public examinations, to informal, school-based, non-competitive assessment. The three-fold significance of Broadfoot's model in relation to this study was noted. First, her model demonstrated the importance of external tests as a legitimating agent. Second, although Broadfoot did not make any links between her own work and that of Bernstein and Young, these links clearly exist. Formal assessment, in Broadfoot's terms, is part of Bernstein's collection code and Young's high status knowledge and, conversely, informal assessment, in her terms, is part of Bernstein's integrated code and Young's low status knowledge. As shown in Figure 2.5, it was possible, therefore, to include Broadfoot's dimensions of assessment in the developing theoretical framework. Third and, again, although the connections were not made by Broadfoot herself, her model has important links to the interaction between gender and assessment, an area explored in more detail in Chapter 4 of this thesis.

The Emerging Framework: Application to Gender-Based Hierarchies of Knowledge

The next step in the theory-building process, as described in Chapter 4, was to explore the extent to which the emerging theoretical framework had application to gender-based hierarchies of school science knowledge. The chapter focused on previous research, conducted mainly by science educators, bearing on the contribution to the gender/science

relationship made by schools, school systems and science curricula. Essentially, the concern, in this case, was with the manner in which school science curriculum and assessment policy and practice appear to interact with school science. It was argued that schools and school systems can make a difference to the way in which the relationship between gender and science develops and endures, given appropriate conditions. By drawing on a range of research conducted in schools and school systems, the chapter was able to identify these conditions. In addition, it was able to present a review of strategies which appeared to have been successful, in many different parts of the world, in humanising the masculine image of science. In this sense, the present study moved well beyond most previous analyses, which have tended to conjecture about the characteristics of a gender-inclusive curriculum, rather than to present evaluative evidence about these characteristics.

Thus, this study was able to build, from empirical evidence about school- and system-based practices, an image of a more gender-inclusive school science. Further, because of its grounding in theories derived from the sociology of knowledge, this study was able to analyse these practices (in terms of the initial theoretical framework developed in Chapter 2) and position this image with respect to Bernstein's collection code and integrated code, Young's high and low status knowledge and Broadfoots' continuum of formal/informal assessment.

Features of Successful Strategies

A review of evaluative research conducted principally in the US (e.g. Malcom, 1984; Stage et al, 1985), but supported also by examples from elsewhere in the world, established a set of conditions which appear to be prerequisites for the success of school- and system-based initiatives in the area of gender and science. These prerequisites focus on the need for

- a multifaceted approach
- specific targetting (and the concomitant recognition of the limitations of programs designated "for all")
- avoidance of premature mainstreaming (or, alternatively, provision of specific equity support for initiatives which are mainstreamed)
- systemic support
- strong and committed leaders
- programs to be sustained in the longer term.

These six points, particularly those concerned with systemic support and initiatives "for all", proved to be especially important in the context of much of the research reviewed and reported in this thesis. A possible seventh requirement for a successful program, namely, a strong "academic" emphasis (defined, apparently, in terms of conventional, academically rigorous science and mathematics leading to careers requiring science and mathematics) was identified by Stage et al (1985). From the perspective of the present study, the concept of a strong academic emphasis is perhaps more contentious in the 1990s than it was in the 1970s. As demonstrated in Chapters 5 and 6 of this thesis, the concept of what constitutes academically rigorous science has been challenged from a number of directions and remains in need of considerable clarification.

Changing the Masculine Image of Science

The review of strategies which appear to have been successful in changing the masculine image of science was structured around two dimensions of Kelly's (1985) reconceptualisation of the ways in which schools contribute to the masculine image, namely, the ways in which school science is "packaged" (which is analogous to Bernstein's concept of

classification) and the ways in which it is "practised" (analogous to Bernstein's framing).

As a result of the analysis reported in this thesis, it was argued that the packaging of a more gender-inclusive science needs, first, to be sex equitable in terms of its language, illustrations and examples [as demonstrated, in particular, by the research of Schau and Scott (1984)]; second, to emphasise social and environmental applications [as demonstrated, in particular by Harding (1985) and Jorg and Wubbels (1987)]; and, third, to be structured in ways which minimise students' capacity to choose amongst scientific disciplines [as shown by the research of Fennema and Sherman (1977), Pallas and Alexander (1983) and others, relating to the differential course-taking hypothesis]. In the more formal terms of the gender code theory, this kind of packaging represents a shift to weaker classification.

It was argued, further, that the practices in a gender-inclusive science curriculum need to emphasise, first, interpersonal negotiation, human interaction, discussion and active participation by students; second, real-life contexts; third, school-based, informal assessment procedures, with relatively open-ended tasks drawing on contexts which are familiar to both males and females; and, fourth, attention to students' self-awareness of the extent to which their education-related decisions and experiences are socially constructed, and are the products of hegemonic influences on themselves and their teachers. In this case, in the formal terms of the emerging gender-code theory, this shift represents a shift towards weaker framing.

Overall, then, gender-inclusive science emerged as a more integrated code curriculum than traditional science. This raised questions about its perceived status, rigour and legitimacy, especially in terms of Young's (1971b) theories and in terms of Irigaray's (1985) three

prerequisites for rigorous science, namely, an emphasis on symbols, on quantification and on formalised language (cited in Grosz and de Lepervanche, 1988). These questions were pursued systematically in this study, as reported in Chapter 6.

The Gaps in the Research Background

The literature review in Chapter 4 revealed two notable absences from previous research. These were, first, the absence of research on the gender effect of changes in individual science subjects at the senior secondary level (e.g. either through the introduction of a new curriculum or through reform of an existing curriculum) and, second, the absence of research on the gender effect of changes in system-wide science curriculum and assessment structures at the senior secondary level. These two gaps were explored in detail in this study, as reported in Chapters 6-8 of this thesis.

Linking the Empirical to the Theoretical:

Feminist Scholarship on Gender and Science

Much of the empirical research reviewed in Chapter 4 was conducted in the absence of any integrating theory. Importantly, the research took place during the approximately 15 year period of history which saw also the emergence of the postmodernist feminist critique of science. Yet, until very recently, there was little dialogue between the researchers involved in these two strands of activity. Given their common concerns, however, it was important to establish the extent to which these two strands, from quite different origins, had converged. A review therefore was undertaken of the postmodernist feminist critique of science, focusing specifically on the strand concerned with the definition of science. As reported in Chapter 5, this review dealt in

considerable detail with the work of Keller (1978, 1982, 1983, 1985, 1989) and discussed the contributions of other postmodernist feminists in relation to specific aspects of Keller's work on the definition of science, in particular in relation to the social construction of masculinity, femininity and science.

In the discussion of feminist scholarship, the issue of dualisms also was addressed (an issue which is quite fundamental to this study, given that the emerging theoretical framework was conceptualised as a grid-group classification). It was pointed out that, in relation to the postmodernist feminist critique of science, the representations of "masculine" and "feminine" sciences, which are the outcomes of some analyses [e.g. Ginzberg's (1989) gynocentric science and androcentric science] leads to a set of dichotomies or dualisms. These can be seen as rival paradigms, associated with irresolvable conflict and competition; in the event of one or other paradigm triumphing in this competition, the triumph would be construed, in Keller's terms, as the substitution of "one form of parochiality for another" (1985, p. 178). Alternatively, they can be seen as complementary, with a "reclaimed" science ultimately enriched because of the diversity of perspectives. This study argued for the latter view.

At this point in the study, the summary image of gender-inclusive science distilled from the postmodernist feminist critique was translated into a picture of a gender-inclusive school science curriculum. Again, what emerges is an integrated code rather than a collection code curriculum. With respect to classification, the curriculum content includes the "her-story" and the "lost women" of science and a discussion of the evolution, use and abuse of scientific knowledge. It also expands the boundaries of "science" to include science which takes place in domestic and nurturant contexts. In addition, the curriculum content

projects an holistic, non-hierarchical view of science, with diversity a part of the integrity of the discipline. With respect to framing, the pedagogy and assessment procedures take account of diverse ways of knowing, viewing and describing the world. They also provide opportunities for personal involvement of students with science and for discussion of the extent to which science is value free and "objective".

Overall, it was argued that this image mirrors the empirically established image (developed in Chapter 4) and that the combined theoretical/empirical picture can be mapped onto the theoretical framework developed in Chapter 2. It was emphasised, however, that even this enriched image of school science, with its explicit acknowledgment of diversity, risks being mapped also onto a gender dichotomy (or, in the terms of this study, gender coded) and risks being viewed as low status, less worthwhile knowledge than that presented in traditional science curricula.

The Gender Code Theory

With the completion of the major synthesis of research from curriculum theory, feminist theory and science education, it was possible to formulate a hypothesis regarding the gender coding of school science, with a code defined, in Bernstein's (1990) terms as "a regulative principle, tacitly acquired, which selects and integrates relevant meaning, forms of realizations and evoking contexts" (p. 101). The gender code theory, represented diagrammatically in Figure 9.1, states that *school science is gender coded in ways which associate maleness with Bernstein's collection code, Young's high status knowledge and high legitimacy because of Broadfoot's formal assessment procedures; and conversely, which associate femaleness with Bernstein's integrated code, Young's low status knowledge and low legitimacy because of Broadfoot's informal*

assessment procedures. Essentially, the research reported in Chapters 6, 7 and 8 of this thesis constituted a testing of this hypothesis.

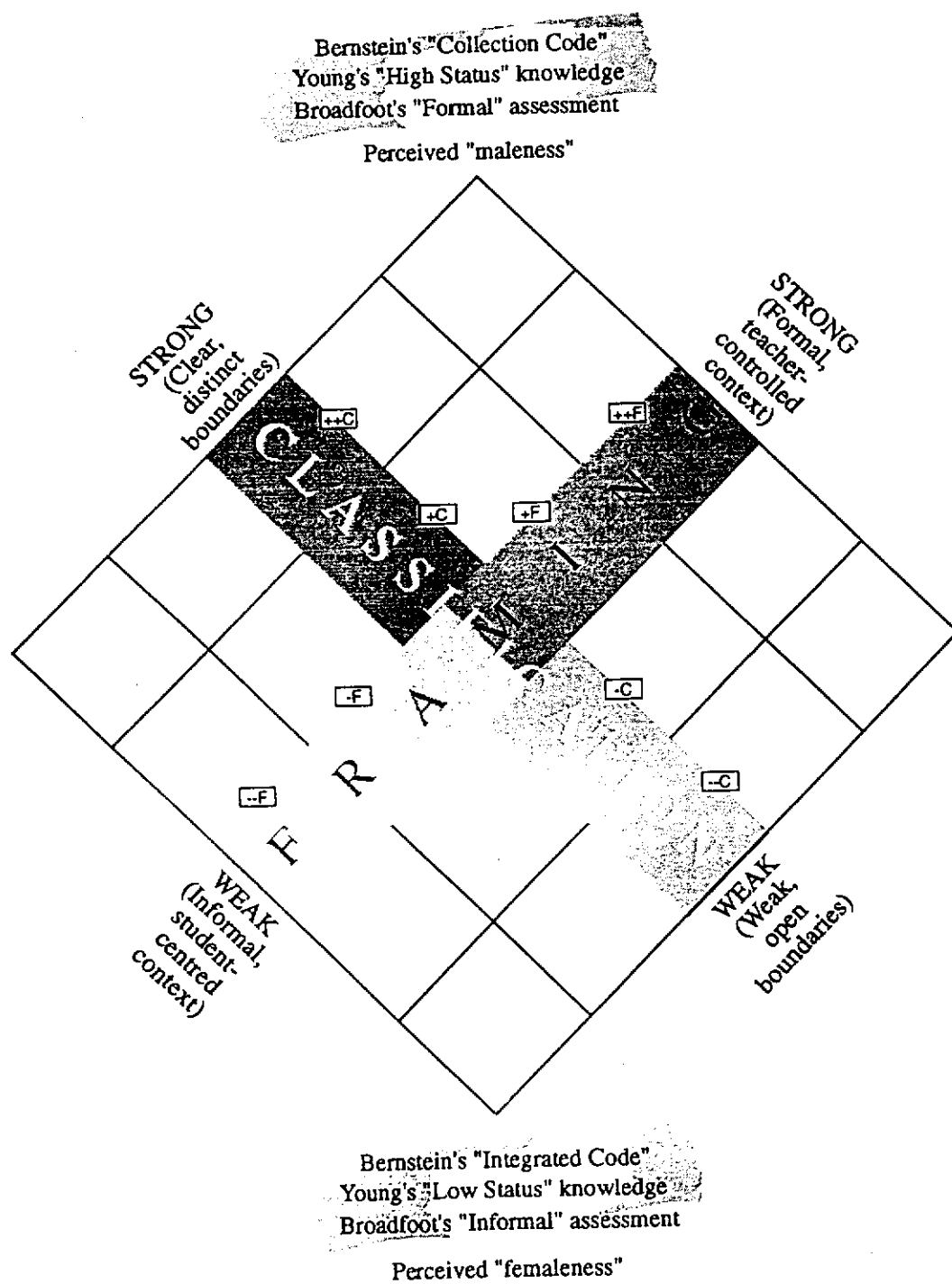


Figure 9.1. Diagrammatic representation of the gender code theory.

SYNOPSIS OF CHAPTERS 6–8: THE TESTING OF THE GENDER CODE THEORY

The Socio-historical Analysis

The socio-historical analysis conducted in this study focused on the two gaps in research revealed by the literature review in Chapter 4. Both gaps concerned the gender effects of science curriculum changes (as manifested through patterns of sex-differences in participation and achievement). One gap concerned these effects in relation to changes involving an individual science subject and the other concerned the effects in relation to system-wide changes in the whole science curriculum. There were three major research tasks. First, an extensive data base was developed and analysed, pertaining to students' participation and achievement in upper secondary school in Western Australia during the years 1976–1993. Second, a wide variety of documents and reports were scrutinised, synthesised and interpreted, pertaining to policies and reforms affecting the structure of science curriculum and assessment in Western Australia during the years 1969–1993. Third, historical links between curriculum/assessment policy changes and patterns of science participation/achievement were sought, with the aim of identifying recurring patterns and possible systematic effects, particularly in terms of the theoretical framework of this study.

The First Gap: A Science-for-All Subject at Senior Secondary Level

The exploration of the first gap is reported in Chapter 6, focusing on theoretical and practical issues surrounding several attempts, in different parts of the world, to translate the concept of science-for-all into a viable curriculum for senior secondary school students. Using the

example of the implementation of *Physical Science* in Western Australia in 1978–1979, the study explored the extent to which the availability of this subject appeared to make a difference to the relationship between gender and science, in terms of students' enrolment and achievement. In so doing, it drew attention to the close similarity between curricula aimed at science-for-all and curricula aimed at gender-inclusiveness. It was noted that, partly as a consequence of the lack of recognition of the similarities between the two, the potential of science-for-all curricula in relation to gender-inclusiveness appears neither to have been understood, nor to have been realised fully. It was pointed out that full realisation of this potential requires attention to Malcom's (1984) finding that specific targetting of gender-inclusiveness is necessary if the programs "for all" are to be successful in influencing the way females and males relate to science.

The socio-historical analysis reported in Chapter 6 lent support to the Bernstein/Young dimensions of the gender code model. Specifically, the more relevant, less individualistically-oriented, integrated code subject *Physical Science* was perceived to be less difficult and of lower status than its traditional, unrelated, individualistic, collection code counterparts *Physics* and *Chemistry*, despite the official information advising to the contrary. This perception, moreover, was found to be both pervasive and powerful, shared by students and school staff alike, though held less powerfully by female students than by male students. These perceptions appeared also to have led to *Physical Science* being seen as more suitable than *Physics* and *Chemistry* for girls, even for girls who had demonstrated high ability in science and mathematics.

The analysis raised the issue of the perceived rigour and legitimacy of science-for-all subjects. The evidence suggested that science-for-all is not perceived as "real" science and, in so doing, supported Young's (1977)

contention that academic curricula involve assumptions that some kinds of knowledge are more worthwhile than others and Irigaray's (1985) set of preconditions believed to be necessary for scientific rigour. These assumptions are similar to what Mannheim defined as ideologies, acting to sustain the values, power and privilege of specific groups. As Young emphasised, changes to academic curricula tend to be tolerated only to the extent that they do not undermine this set of values, power and privilege. Overall, the analysis carried out in this study revealed the two-fold failure of science-for-all – on the one hand, involving its perceived legitimacy and, on the other hand, involving inattention to the targeting of gender-inclusiveness.

The Second Gap: System-wide Science Curriculum Change

The exploration of the second gap is reported in Chapters 7 and 8. Chapter 7 reports the comprehensive analysis of sex differences in science curriculum and achievement in secondary school science under various system-wide curriculum and assessment structures operating in Western Australia between 1969 and 1993. The analysis demonstrated again the links between integrated code science curriculum structures and increased female participation and achievement, thus adding further to the bank of confirmatory evidence for the gender code theory. Chapter 8 then reports the findings of a more detailed exploration, focused on the years 1985–1993. With some minor qualifications, this more detailed analysis provided further confirmatory evidence for the gender code theory, especially the dimension associated with Broadfoot's typology of different modes of assessment. Specifically, it revealed a systematic effect, over an eight year period, concerning the apparent advantage to males, of external examinations and, to females, of school-based assessment, even school-based assessment based on modernist assumptions. In addition,

the analysis suggested a possible interaction between gender and class, with females of low socio-economic status especially at risk in relation to enrolment in collection code science subjects. Like Chapter 6, the analysis confirmed also the ideological basis of definitions of high status subjects and of rigour. As Kahle (1990) has noted, generally, it is both assumed and expected that "'real' science students take *Physics* and *Chemistry*" and, as demonstrated in this study, "real" science students are both assumed and expected to be what Andrich (1989) has called "highly resourced" students – male, of high socioeconomic status and of high ability.

In summary, the socio-historical analysis reported in Chapters 6-8 of this thesis provided considerable support for the gender-code theory, especially with respect to the systematic, long term gender effect associated with different modes of assessment. Some evidence was identified which initially was considered to be disconfirmatory (for example, in relation to low enrolments in the strongly classified subject *Geology*, and the increasing enrolments in recent years in the weakly classified subject *Senior Science*). This evidence suggested, however, that the dimension of strong classification concerned with links to further or higher education was of paramount importance. This issue is an important one to pursue in future research, as is the other piece of apparently disconfirming evidence from this study. The latter evidence relates to the limited change in enrolment patterns following the recent implementation of the recommendations of the Andrich (1989) review, recommendations which shifted the curriculum slightly towards a more collection code model. Methodological decisions, such as those discussed in the following section, also will be important to address in the context of future studies of the gender code of school science.

THE METHODOLOGICAL DECISIONS OF THIS STUDY: A PERSONAL REFLECTION AND EVALUATION

The Personal Perspective

As indicated earlier, each of the two phases of this study involved a number of methodological decisions. These decisions were taken for a range of methodological and personal reasons. Because of the intensely personal dimensions of this study, it is most appropriate to evaluate and reflect upon these decisions from an explicitly personal perspective, using the first person pronoun. Like Dewey (1958), I regarded this study as a dialectical interaction between myself, as the enquirer, and the gender/science relationship, as the enquired. As Heldke (1989, p. 111) has noted, from this perspective, "gone is the glass wall that separates the inquiring 'subject' from the inquired-into 'object'". I did not attempt to stand behind any such wall or to remain untouched by what traditional research might say was behind it. Notwithstanding my initial training in the physical sciences, I believe, like Rose (1985), that

there is no neutrality. There is only a greater or lesser awareness of one's bias. And if you do not appreciate the force of what you're leaving out, you are not fully in command of what you're doing.

(Rose, 1985, p. 77)

Thus, in this section, I discuss each of the major decisions I took during the study, treating them in approximately the chronological order in which they were taken. I present the rationale for each, together with some comments on the implications of the decision in relation to the limitations and applications of the study.

The Decision to Focus on Gender and Science

The reasons for the focus of this study on gender and science were almost entirely personal. As indicated in Chapters 1 and 3, during the past two decades, I have become increasingly aware of the dysfunctional consequences, world-wide, of the gender/science relationship for males, for females and for science. For females, in particular, I see the patterns of sex differences in participation and achievement in school science as linked to a generalised perception of the limitations of females' capabilities. I believe that opportunities should not be limited by gendered perceptions and, in my professional practice, I am committed to research which endeavours to increase understanding of why this happens and to action which tries to stop it happening. I understand that this perspective is not shared by all educators. Like Jean Blackburn (1982), however, I hold to my view that the world would be a better place if its inhabitants' experiences, and their knowledge (especially scientific knowledge), were not gendered.

The Decision to Adopt a Sociology of Knowledge Perspective

I took the decision to work within the sociology of knowledge paradigm because, from an epistemological perspective, I considered it was essential for this study to have embedded in it, as an integral part of the study, the capacity to question taken-for-granted assumptions about worthwhile knowledge. From my reading of the critics of the sociology of knowledge approach (e.g. Popper, 1962; Pring, 1972), I recognised the potential intellectual dangers of this perspective. Merton, for example, has commented, in relation to sociology of knowledge analyses, that,

[W]hatever the intention of the analysts, their analyses tend to have an acrid quality: they tend to indict, secularize, ironicize, satirize, alienate, devalue the intrinsic content of the avowed belief or point of view.

(Merton, quoted in Stark, 1958, p. 155)

This suggests that there is a debunking element in discussions conducted from this perspective, which, in turn, can disguise the polemical intentions of a piece of work. Naturally, I have tried to avoid this particular pitfall, but whether I have done so successfully must be judged by the readers of this thesis.

In taking the decision to adopt the sociology of knowledge approach, I was conscious also of Karabel and Halsey's (1977, p. 54) warning that, at least in the years immediately following the launch of the "new" sociology of education, it had led to "many departures but disturbingly few arrivals" in a research sense. Given the large number of phenomenological and ethnographic studies of classroom processes during the past decade, studies which owe much to the "new" sociology of education, I considered that Karabel and Halsey's judgment might have been somewhat premature. I considered also, however, that the existing range of interpretive studies needed to be complemented by a study focused more on the structural level of education (as discussed below in the context of one of my later decisions).

The Decision to Build a Theory

As indicated in Chapter 1, in my experience with the science education community (especially the international GASAT community), I became acutely aware of lack of theoretical underpinnings of most of the empirical research on gender and

science. Because of my perception of the difficulty of theory-building, however, my actual decision to attempt to build a theory was taken somewhat reluctantly and only after some urging from colleagues. Once I appreciated that, as Van Dalen (1979) pointed out, theory-building is cumulative, proceeding by adding "something to previously established knowledge by supporting, qualifying, refuting, or enlarging upon existing theories" (p. 79), I became much more comfortable with this decision. I realised that my theory was likely to be only a part of the incremental growth in understanding of a complex social issue.

In the event, I believe this study has demonstrated that the gender code theory developed and tested here satisfies well the criteria of description and prediction, which are fundamental to the definition of a theory (see Hawking, 1988; O'Connor, 1957; Wiersma, 1986). However, a different kind of study, focusing in considerably more detail on participants' interpretations of events, would be needed to establish whether the gender code theory is able to fulfil the third function of a theory proposed by some philosophers, namely, explanation.

The Decision to Build a Theory by Weaving Together Strands from Existing Theories

I have, for many years, been attracted to the theorising of Berger and Luckmann (1967) and to their ingenious weaving together of several strands of existing theory to form their theory about the social construction of reality. My previous experience with this kind of intellectual exercise, although limited, had been rewarding [as seen, for example, in a previous analysis which established links between gender-inclusive and constructivist curricula (Parker & Rennie, 1992)].

For the present study, from the point of view of methodological rigour, I considered, like Karabel and Halsey (1977), that my use of multiple perspectives (from the sociology of knowledge, postmodernist feminism and empirical research on gender and science) was part of an eclecticism which would add strength to my research. I used these multiple perspectives in terms of what Denzin (1988, p. 512) has called "theory triangulation" – the use of multiple theories to interpret the same phenomenon. In addition, I was somewhat inspired by Ginsberg and Meyenn's (1979) prediction that the synthesis of major perspectives in this way would lead to a "new and propitious era of educational research" (p. 96).

Clearly, the validity of this approach to theory-building is very difficult to establish in the short term. Perhaps, in the long term, durability and citations (as in the case of Berger and Luckmann) will be the most appropriate criteria for judging success. For the present, I was encouraged to find, towards the end of the study, that such a distinguished educational researcher as Popkewitz (1994, p. 5) shared my view that there is a need "to foster systematic discussions [about curriculum] among the different intellectual schools within the field".

The Decision to Focus on Critique and Action

As intimated in the above discussion of my first decision, there was a reformist agenda to this study. As emphasised by Shymansky and Kyle,

[E]vidence is mounting that the archaic ritual of 'transmission and acquisition of knowledge' is not able to provide students with the science and technology requisite for future human needs.

(Shymansky & Kyle, 1992, p. 754)

I considered that there have to be better ways of structuring the science education of both boys and girls and I aimed for my study to help in the search for those better ways. In doing so, I noted, like (Young, 1977) that a commitment to both critique and action was necessary. Through the critique which I undertook as part of this study I was able to conceptualise hierarchies of school science knowledge, but the critique alone would be of little relevance to my total agenda. These hierarchies needed also to be explained, not as the order of things, but as the outcomes of the collective actions of people and, thus, "understandable and potentially changeable" (Young, 1977, p. 247). I began this study with the hope that its implications for research on gender and science and for curriculum and assessment policy and practice in schools and school systems would be profound. I saw the study's strong grounding in both critique and action as insurance, in a sense, that its implications would be recognised and acted upon.

The Decision to Start with Bernstein and Young

In the mid-1980s, I became fascinated with the writings of the new sociology of education. For me, they opened up a whole new world of questions which had been ignored by traditional sociology of education. I recognised the need to avoid the extreme relativism which can be part of the Bernstein/Young perspective and aimed to be, essentially, constructive and forward-looking, not destructive and, as indicated above, "debunking". I also enjoyed the intellectual challenge of interpreting the work of Bernstein and Young and shared with Davies (1994), the feeling that their potential has not yet been realised fully. I knew from the outset of this study that engaging with the ideas of Bernstein and Young was not going to be an easy task.

However, as Davies (1994) has noted, the notion that their theories are not amenable to research applications is for the faint-hearted, who are "unwilling to persevere with ideas that do not deliver a self-announcing, feel-good factor" (p. 19).

The Decision to Use a Grid-Group Classification

For me, grid-group classifications always have been useful as tools for organising the social world and as tools for explaining the social world to others. In the latter context, my initial conceptualisation of Bernstein's codes in this fashion met with some success as a way of representing some of his complex theorising to Bachelor and Master's students in curriculum studies.

I share with Ostrander (1982), however, some misgivings regarding the limitations of the applicability of grid-group classifications. For example, I understand that they are relative and not absolute tools and I see them as constructed of continuous rather than dichotomous variables. I understand also that they are not causal models. They can summarise the complexities of a situation and they can be used to predict what is likely to happen in similar situations, but they cannot explain fully why this happens. I appreciate, also, that the kind of grid-group classification which I have developed is not the only classification possible that links social structure to symbolic structure. As Ostrander (1982, p. 15) noted, almost all theoretical frameworks make this linkage, if only implicitly. In the case of grid-group classifications, the link is explicit, which makes them relatively easy to interpret and apply.

As indicated earlier in this chapter, I needed to confront the dualistic traps potentially embedded in the grid-group format. In this regard, I found the perspectives of Keller (1985) and Lemke (1994) particularly helpful, as discussed in Chapter 5. As Lemke (1994)

emphasised, it is not the dualisms as such which create a problem, it is the disjunction read into the dualisms and the perception of the two poles of the duality as mutually exclusive. Thus, I present my grid-group analysis as a thinking tool, involving mutually dependent and complementary concepts, not as an absolute representation of the world, with oppositional, mutually exclusive concepts. I suggest that Bernstein's concepts of strong and weak classification and framing are really concerned with a continuum of classification and framing. I am concerned, nevertheless, that the kind of framing which appears to advantage males is labelled strong, while that which includes females is labelled weak. I consider that this kind of labelling can have far-reaching, debilitating consequences for the generalised perception of female attributes, and needs, if possible, to be avoided in the future.

The Decision to Incorporate Feminist Theory

There were both personal and methodological reasons for my decision to incorporate feminist theory as one of the strands of this study. I know, from personal experience, that "gender is a fundamental category within which meaning and value are assigned to everything in the world" (S. Harding, 1986, p. 57). I also am attracted by the basic tenets of feminist research, which include not only the focus on gender and the questioning of accepted ways of viewing the world, but also a foregrounding of women's experiences as a scientific resource and an insistence on gender-reflexive practices by the research. I consider that one of the major contributions of this study has been its identification of what essentially is a match between gender-inclusive science from a practitioner's perspective [i.e. the kind of science girls (and many boys) like to do and, furthermore, do very well in, as described in Chapter 4 of this thesis] and gender-inclusive

science from the theoretical perspective of postmodernist feminism (as described in Chapter 5 of this thesis). As indicated earlier, the practitioners and the postmodernist feminists were working over the same approximately 15 year period between the late 1970s and the mid-1990s, but until very recently, somewhat in isolation from one-anothers' concerns. I saw it as important, therefore, to establish the extent to which their conclusions were consistent with one another.

The Decision to Conduct a Socio-historical Analysis

Again, I made the decision to undertake a socio-historical study partly on the basis of personal experience and partly on methodological grounds. Professionally, I had been in a position, for some years, to observe the outcomes of various curriculum and assessment structures and to understand the value of establishing historical trends of patterns of enrolment and achievement. Thus, I was able to triangulate from data analysis, document searches and personal observations over an extended period of time. I also appreciated, like Goodson (1983, 1985) that the socio-historical approach optimises the possibilities for understanding curriculum issues and curriculum change. I found the approach to have particular advantages in relation to, first, being able to offer insights into patterns of participation and achievement (not just sex-related patterns, but also those related to socio-economic status, which had not been done previously by Bernstein or Young, despite their focus on class); second, being able to link these patterns to changes in curriculum and assessment structures; and, third, being able to infer from the links and patterns and from reactions to them, something of the ideological basis of education.

As the study progressed I became more and more convinced of the validity of this approach. The historical dimension lent considerable power to my findings and the sociological dimension alerted me, not only to the social context of the study, but also to the importance of people's reactions to my preliminary findings. Nowhere was this twin relationship more evident than in the instance of my discovery of the differences in gender effect sizes under the pre-McGaw examination system and the post-McGaw system based more on school based assessment. Although I knew, from the outset of this study, of the research demonstrating higher achievement by males on multiple-choice tests and by females on extended response items, I knew of no previous work which had explored, longitudinally and systematically, the sex difference in measured achievement under external compared with school-based assessment, as I was able to do in this study.

People's reactions to my preliminary findings proved, however, also to be important in the sense of exposing the hegemonic influences at work in society. My first, tentative analysis was based on data from only three years (1986–1988). Reactions to my findings, at that stage, were generally along the lines of assurances that the system was new and would "settle down" (which appeared to mean settle down to a situation where boys' achievement in the physical sciences was universally superior to that of girls). When this did not happen and the trend continued to show up, typical reactions challenged the data, ignored the findings, or questioned the validity and rigour of school-based assessment. Thus, the historical approach had revealed the trend, but the sociological approach revealed the underlying ideology concerning beliefs about the limits on females' achievement,

especially in the physical sciences. Together, they highlighted the importance of the assessment dimension of the gender code theory.

The Decision to Focus on System-wide Curriculum and Assessment Structures

As indicated above, much of the research which followed the new sociology of education had been interpretive research focused on events in schools and classrooms. Relatively speaking, the structural level had been neglected, except for some previous work on assessment, especially examinations (e.g. Broadfoot 1969, 1984). Like Hargreaves (1989), however, I believe that the structural level is "the one at which much of the future of schooling is now being shaped" (p. 68). Further, like Shymansky and Kyle (1992), I consider that one of the crucial questions for science education concerns the key attributes of effective, systemic curriculum reform. In selecting the structural level, I was conscious also that this level is particularly critical (although indirectly), to what goes on in the classroom. Especially in centralised systems such as Western Australia, the centrally mandated curriculum structure and the centrally prepared and mandated syllabuses and assessment structures provide the foundation for, and the constraints on, what teachers and students do in the classroom. Thus, although studies such as this need to be complemented by detailed, classroom-based research, they have an important role also in their own right.

In particular, I see the focus on the structural level as having important implications when it comes to the generalisability of the findings of this study. Some have suggested (e.g. Karabel & Halsey, 1977) that studies emerging from the new sociology of education are "almost entirely a British creation" (p. 47) and have limited relevance,

especially in the US (because, as Karabel and Halsey saw it, the US is a "young, populist and classless society"). The implication of this would be that studies such as mine are generalisable only to other similar education systems, where there is a relatively strong centralised control of the school curriculum, enforced through an examination system linked to future study and employment (e.g. France and the UK). My knowledge of recent developments in the UK and in the Australian State of Victoria suggest that generalisation to such systems certainly has validity. For example, as reported recently by Murphy (1993) for the UK and Hildebrand and Allard (1993) for Victoria, the superior achievement of females on school-based assessment also has been noted. In both places, however, the gender code and the ideology mitigating against high achievement by females appears to have surfaced – both systems were changed, after one year, to re-establish a greater emphasis on external examinations.

I believe that there are, however, other issues concerning the generalisability of structural level studies. I question whether studies such as mine are generalisable only to similarly structured education systems. From much of the international research cited throughout this thesis [including studies such as those of Kliebard (1986) focused on the US] it appears that subject stratification and status issues are endemic in all school curricula. In this context, a number of interesting questions arise for future research to address – for example, how does the gender code and its legitimation operate in countries where there is no system-wide external examination to act as the legitimating agent?

The Decision to Focus on State-wide Data

I chose to use the Western Australian State-wide data base, because it was accessible, accurate and comprehensive in terms of detail and in terms of the span of many years. I knew it would have certain disadvantages because of the limitations of the data-gathering (for example, the background characteristics and results of individual students were not available, which limited the kinds of analyses that could be carried out). From my feminist perspective, I found the greatest disadvantage of the State-wide data was that they suggested that females and males are homogeneous groups. I am careful to avoid any such suggestion in the presentation of my findings.

The State-wide achievement data, however, lent themselves to the calculation of effect sizes. I was satisfied that the effect size is recognised widely as a robust statistic and very convenient means of representing differences between groups. I was satisfied, in addition, that the effect size statistic would provide a conservative (i.e. not an exaggerated) estimate of the sex differences in achievement.

I had also a purely pragmatic reason for the use of the State-wide data base. As indicated earlier, I aimed for my study to inform policy and practice in science education. I knew, from previous experience, that educational policy-makers and practitioners are extremely sceptical about the findings of research which challenges their beliefs (for example about gender and science or about gender and achievement). Thus, I knew it would be important for my study to have some grounding in conventional, virtually unchallengeable, highly legitimate data. This, I felt would maximise the possibility of its acceptance by the education decision-makers, although I recognise (like Yates, 1993) that, at least in Australia, curriculum policy has been influenced very little by curriculum theories such as the gender code

theory. This raises questions regarding the possibilities for change, which I address in the next section.

THE POSSIBILITIES FOR CHANGE

What, then, of the possibilities for change in curriculum policy and practice to make school science more gender-inclusive? The research of Davies (1989a, 1989b) has suggested that it might not be easy to make the kinds of changes advocated in this thesis. Davies demonstrated that, with respect to the construction of gender in schools, it is simplistic to assume that students are only emulating role models or acting out innate drives. Rather, she found that they were trying to make sense of their particular culture. Thus, if the culture presents males and females in terms of oppositional qualities and, in the manner described earlier, maps these oppositional qualities onto oppositional ways of knowing, part of the students' acquisition of language and social competence depends on their acceptance and internalising of these dualisms [or, as Berger and Luckmann (1967, p. 87) would term it, the "integration" of the dualisms into each individual's experience]. Attempts to change to any alternative form of science in schools therefore need to be made with a full understanding of the dysfunctional consequences of such gender-coding and to include specific strategies to avoid these consequences.

In a practical sense, Malcom's (1984) evaluative research and analysis of curriculum change, as I discussed in Chapter 4 of this thesis, was especially helpful in suggesting ways to implement a more gender-inclusive science curriculum. Her point about the need for strong systemic support underscores, for me, the need for teacher inservice and materials to support the curriculum change. Her point about a multifaceted approach underlines, for me, the need to focus on the

syllabus, the pedagogy and the assessment, in other words, on all three of Bernstein's message systems. In addition, I find especially salient her point about the trap inherent in believing that programs "for-all" will necessarily include females. Indeed, as a result of this study, I have added to this another trap, namely, the one associated with seeing science-for-all as not "real" science and therefore as suitable mainly (or even only) for females and students of low socio-economic status.

What then of the need for a strong academic emphasis in gender-inclusive science curricula, as suggested by Stage et al (1985)? I would maintain that this depends on the way academic rigour is defined. Rigour, as defined by Irigaray (1985, cited in Grosz and de Lepervanche, 1988, p. 26), involves the conventional dimensions of "precision, accuracy, repeatability, a neutral, clear language, a clear-cut set of procedures for assessing propositions, a manipulable, controllable set of experimental techniques", not because these attributes are intrinsic to "real" science, but because the traditional scientific knower has required "a set of guarantees about the stability and certainty of his position". Defined in this way, rigour can be seen, in Mannheim's (1936) terms, as an ideology – difficult to validate by empirical means, arising in a specific social setting and providing support for a particular group in the community.

Now, the image of a gender-inclusive science curriculum, as I have drawn it in Chapters 4 and 5 of this thesis, does not appear to conform to Irigaray's basic tenets of scientific rigour. But, I ask myself, if rigour is an ideology, why can rigour not be defined differently? What, for example, if rigour were redefined in accordance with Andrich's (1989) definition, as dependent on *representational*, *experiential* and *reflective* components? My image of a gender-inclusive science curriculum is strong on *representation*, although not so much in terms of

mathematical symbols as in terms of the symbols of spoken and written language. Similarly, it is very strong on *experience*, emphasising active participation by students in real-life contexts. Further, in comparison to the traditional TEE syllabuses, it is exceptionally strong on *reflection*, emphasising, in particular, the need for students to reflect on their own decisions, learnings and experiences in science and to see these as contextualised in history and contemporary society. Does change to a gender-inclusive science curriculum then involve a redefinition of the ideology of rigour, perhaps along the lines recommended by Andrich? Again, this is an interesting question to explore in future research.

With respect to change, Keller's (1985) perspective on whether and how the dominant paradigm in science copes with challenges also is valuable in the context of school science. Essentially she was optimistic about the possibility of change, but cautioned, as noted earlier, that any change to the dominant paradigm is likely to meet with "a web of internal resistance" (1985, p. 136) and that it must take place not by discontinuity, but by growth from within. Birke (1986a) suggested also that effecting a change in science is "perfectly feasible". She observed, however, that it is probably more realistic to "consider changing the ways in which we teach and think about our relationship with nature, to make it more acceptable and less alienating – to reintroduce...the human face of science" (p. 195). As a biologist, Birke argued for a decrease in the impersonal, reductionist and mechanistic in science and, in this sense, found encouragement in the influence of the "green" movement on shifting both science and science education towards a more holistic view. Her view was that the dominance of reductionist modes of thought in areas such as molecular biology is decreasing and, in this sense, she noted a shift towards an increasing interconnectedness of cellular and molecular events and a changing perception of DNA as no longer the

"master molecule" but more a part of a complex system. Overall, her perspective on change as emerging by growth from within, rather than by discontinuity from outside science and science education, clearly was similar to Keller's.

The possibilities for change in the school science curriculum are linked also to the dominance of the influence of modernism on school curricula. Collins (1993b, p. 10) has emphasised that "the key words of modernism are the motto words of the school curriculum: measuring, classifying, thinking, reasoning, objectivity, truth". In a similar vein, Hextall and Sarup (1976) argued earlier that students in schools, as part of their enculturation into the "culture of positivism", are initiated into a world where everything is measured and graded. Together with many others in the sociology of education [see Whitty (1976); Young and Whitty (1977)], they argued further that there is considerable resistance to anything which is seen as challenging the epitome of this measurement and grading process – the external examination – and demonstrated the quite severe constraints which examination boards in the UK placed on curriculum change.

Overall, it appears that a change to a more integrated code school science curriculum involves a challenge to at least two of the central features of the manifestation of modernism in education – a challenge to the traditional, "objective", physical science model of worthwhile knowledge and a challenge to traditional, "objective" ways of assessment. The task is indeed quite formidable. I look to the future optimistically, however. As Rorty (1986) has remarked:

When we began theorizing our experiences during the second women's movement a mere decade and a half ago, we knew our task would be a difficult though exciting one. But I doubt that in our wildest dreams we ever imagined we would have to reinvent

both science and theorizing itself in order to make sense of women's social experience.

(Rorty, quoted in S. Harding, 1986, p. 251)

CONCLUDING COMMENTS

For the title of this final chapter, I appropriated and adapted, quite blatantly, Bernstein's famous *Class, Codes and Control*, the title of the four volumes of his research and theorising. Just as Bernstein's theories sought to describe and explain the relationship between social class and knowledge, so have I, with the gender code theory, sought to increase understanding of the relationship between gender and knowledge, especially, in this case, scientific knowledge, at the secondary school level. I have demonstrated the applicability of gender code theory to the description and prediction of the current situation in science education. Like Heldke, however, I offer this new gender code theory

in the spirit of a cook who passes out copies of favorite, well tested recipes. It has proven reliable for me, and I'm willing to claim that it will work equally well in other contexts. But, as with recipes, I'd argue that no epistemological program works in all contexts for all users.

(Heldke, 1989, p. 105)

My hope is that ultimately, the theory will be of historical significance only, because at some point in the future, I would hope that an integrated code, gender-inclusive science curriculum becomes what Kuhn (1970) would call "normal" science. In this Utopian world there would be no gender coding of school science, in other words, no gender coding of integrated code science curricula as low status and suitable only for females.

Finally, I note that theories that deal in ideological currency, as the gender code theory does, are highly controversial. Each of the areas of research synthesised in this study has, in its time, been of this ilk. Mannheim's sociology of knowledge was rejected by many distinguished philosophers and declared by Popper (1962), for example, to be "foolish and irrational". Later, the new sociology of education, as pointed out by Davies (1994), drew hostile and vitriolic reactions and suffered numerous attempts to discredit it (e.g. Pring, 1972). Similarly, both postmodernist feminist theory and research on gender and science have struggled, at least initially, to establish their legitimacy in the research and education communities. Also, research on assessment is fraught with controversy, because of the shifts in power and control which are contingent upon system-wide changes in assessment. I am sure that the gender code theory will be no exception to such controversy, but I am hopeful that it will be robust enough to withstand challenges and to inform, constructively and productively, the work of both researchers and practitioners.

LIST OF REFERENCES

- Adams, R.J. (1984). *Sex bias in ASAT*. Melbourne: Australian Council for Educational Research.
- Alcoff, L. (1989). Justifying feminist social science. In N. Tuana (Ed.), *Feminism and science* (pp. 85-103). Bloomington: Indiana University Press.
- Alexander, K.L. & Pallas, A.M. (1983). Reply to Benbow and Stanley. *American Educational Research Journal*, 20 (4), 475-477.
- Alic, M. (1986). *Hypatia's Heritage: A History of Women in Science from Antiquity through the Nineteenth Century*. Boston: Beacon Press.
- Andrich, D. (1989). *Upper secondary certification and tertiary entrance*. Perth: Ministry of Education.
- Andrich, D. & Parker, L.H. (1980). Evaluation of a new Physical Science course: Students' perceptions of its relative difficulty. In *Youth, Schooling and Unemployment*, Proceedings of the Annual Conference, Australian Association for Research in Education, Brisbane, November.
- Apple, M.W. (1978). Ideology, reproduction and educational reform. *Comparative Education Review*, 22, 367-387.
- Apple, M.W. (1979). *Ideology and curriculum*. London: Routledge & Kegan Paul.
- Apple, M.W. (1982). *Cultural and economic reproduction in education*. London: Routledge & Kegan Paul.
- Asekog, B. (1986). *Activities to promote equality of opportunity for girls in technical and vocational education*. Paris: UNESCO.
- Australia. Department of Employment, Education and Training. (1987). *National policy on the education of girls in Australian schools*. Canberra: Australian Government Publishing Service.
- Australia. Commonwealth Schools Commission. (1984). *Girls and tomorrow: The challenge for schools*. Canberra: Australian Government Publishing Service.
- Australia. Schools Commission. (1975). *Girls, school and society*. Canberra: Australian Government Publishing Service.

- Australian Association of Mathematics Teachers. (1990). *National statement on girls and mathematics*. Canberra: Australian Association of Mathematics Teachers.
- Australian Education Council (1991). *Young people's participation in post-compulsory education and training*. Report of the A.E.C. Review Committee. (Chair, Mr T.B. Finn, AO). Canberra: Australian Government Publishing Service.
- Australian Science Teachers Association. (1987). *A policy on girls and women in science education*. Canberra: Australian Science Teachers Association.
- Australian Science and Technology Council. (1987). *Education and national needs*. Canberra: Australian Government Publishing Service.
- Baker, D. (1990). *Gender differences in science: Where they start and where they go*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Atlanta, April.
- Bannister, H. (1988). Truths about assessment and the learning of girls: From gender differences to the production of gendered attainment. In J. Kenway & J. Blackmore (Eds.), *Gender matters in educational administration and policy* (pp. 101-115). London: Falmer.
- Bates, R. (1980). New developments in the new sociology of education. *British Journal of Sociology of Education*, 1 (1), 67-79.
- Bateson, D.J. & Parsons-Chatman, S. (1989). Sex-related differences in science achievement: A possible testing artefact. *International Journal of Science Education*, 11, 371-385.
- Bell, R.C. & Hay, J.A. (1987). Differences and biases in English language examination formats. *British Journal of Educational Psychology*, 57, 212-220.
- Benbow, C.P. & Stanley, J.C. (1980). Sex differences in mathematical ability: Fact or artifact. *Science*, 210, 1029-1031.
- Benbow, C.P. & Stanley, J.C. (1983). Differential course-taking hypothesis revisited. *American Educational Research Journal*, 20 (4), 469-573.
- Ben-Shakhar, G., & Sinai, Y. (1991). Gender differences in multiple-choice tests: the role of differential guessing tendencies. *Journal of Educational Measurement*, 28 (1), 23-35.

- Bentley, D. & Watts, M. (1987). Courting the positive virtues: A case for feminist science. In A. Kelly (Ed.), *Science for girls?* (pp. 89-98). Milton Keynes: Open University Press.
- Benz, C.R., Pfeiffer, I. & Newman, I. (1981). Sex role expectations of classroom teachers, grades 1-12. *American Educational Research Journal*, 18 (3), 289-302.
- Berger, P. L. & Luckmann, T. (1967). *The social construction of reality*. London: The Penguin Press.
- Bernard, J. (1964). *Academic women*. New York: Meridian Books.
- Bernstein, B. (1971a). On the classification and framing of educational knowledge. In M. Young (Ed.), *Knowledge and Control*. London: Collier Macmillan.
- Bernstein, B. (1971b). *Class, codes and control 1: Theoretical studies towards a sociology of language*. London: Routledge.
- Bernstein, B. (1974). Sociology and the sociology of education. In J. Rex (Ed.), *Approaches to sociology*. London: Routledge & Kegan Paul.
- Bernstein, B. (1975). *Class, codes and control 3*. London: Routledge.
- Bernstein, B. (1982). Codes, modalities and the process of cultural reproduction: A model. In M.W. Apple (Ed.), *Cultural and economic reproduction in education* (pp. 304-355). London: Routledge.
- Bernstein, B. (1990). *The structuring of pedagogic discourse*. London: Routledge.
- Birke, L. (1986a). Changing minds: Towards gender equality in science? In J. Harding (Ed.), *Perspectives on gender and science* (pp. 184-202). Lewes: The Falmer Press.
- Birke, L. (1986b). *Women, feminism and biology: The feminist challenge*. New York: Methuen Inc.
- Black, P.J. (1994). Performance assessment and accountability: The experience in England and Wales. *Educational Evaluation and Policy Analysis*, 16 (2), 191-204.
- Blackburn, J. (1982). Becoming equally human: Girls and the secondary curriculum. *WISE News*, July-August, 16-22.
- Bleier, R. (1984). *Science and gender: A critique of biology and its theories on women*. New York: Pergamon Press.

- Bolger, N., & Kellaghan, T. (1990). Method of measurement and gender differences in scholastic achievement. *Journal of Educational Measurement, 27*, 165-174.
- Bossert, S. (1988-89). Cooperative activities in the classroom. *Review of Educational Research, 15*, 125-152.
- Boud, D. Dynan, M.B., Parker, L.H. & Ryan, A.S. (1979). Application of the illuminative model: A discussion of issues arising from the Physical Science Evaluation Project. *Australian Science Teachers Journal, 25* (2), 67-74.
- Bourdieu, P. (1976). The school as a conservative force: Scholastic and cultural inequalities. In R. Dale, G. Esland & M. MacDonald (Eds.), *Schooling and capitalism* (pp. 110-118). London: Routledge & Kegan Paul.
- Bourdieu, P. & Passeron, J.C. (1977). *Reproduction in education, society and culture*. London: Sage.
- Broadfoot, P.M. (1979). *Assessment, schools and society*. London: Methuen.
- Broadfoot, P.M. (1980). Time for a change: The problem of assessment. *New Trends in Education, 23* (1), 18-20.
- Broadfoot, P.M. (1982). Accountability in England and France: The centralist alternative? *Education Policy Bulletin, 10* (1), 55-68.
- Broadfoot, P.M. (1984). *Selection, certification and control. Social issues in educational assessment*. Sussex: Falmer.
- Broadfoot, P.M. (1985). Changing patterns of educational accountability in England and France. *Comparative Education, 21* (3), 273-286.
- Broadfoot, P.M. (1986). Assessment policy and inequality: The United Kingdom experience. *British Journal of Sociology of Education, 7* (2), 205-224.
- Broadfoot, P.M. (1990). Cinderella and the ugly sisters: An assessment policy pantomime in two acts. *The Curriculum Journal, 1* (2), 199-215.
- Broadfoot, P.M. (1993). *Performance assessment in perspective: Some international insights*. Paper prepared for Annual Meeting, American Educational Research Association, Atlanta GA, April.

- Burton, L. (1992). Who assesses whom and to what purpose? In M. Stephens & J. Izard (Eds.), *Reshaping assessment practices in mathematics* (pp. 1-18). Melbourne: Australian Council for Educational Research.
- Byrne, E. (1988). *Women in Science and Technology (WISTA) project*. Draft Report. Brisbane: University of Queensland.
- Campbell, J.R. (1991). The roots of gender inequity in technical areas. *Journal of Research in Science Teaching*, 28 (3), 251-264.
- Chambers, D.W. (1983). Stereotypic images of the scientist: The Draw-a-Scientist Test. *Science Education*, 67, 255-265.
- Chodorow, N. (1978). *The reproduction of mothering: Psychoanalysis and the sociology of gender*. Berkeley: University of California Press.
- Cicourel, A.V. (1974). *Language use and school performance*. New York: Academic Press.
- Coates, B.C. (1994). *Assessment in upper secondary school Geology in Western Australia*. Master of Science Thesis, Curtin University of Technology, Perth, Western Australia.
- Code, L. (1993). Taking subjectivity into account. In L. Alcoff & E. Potter (Eds.), *Feminist epistemologies* (pp. 15-48). New York: Routledge.
- Cohen, (1969). *Statistical power analysis for the behavioral sciences*. New York: Academic Press.
- Collins, C.W. (1989). The changing nature of the academic curriculum. In Australian Council for Educational Research (ed.) *Developing a comprehensive curriculum for the senior secondary years*. Melbourne: ACER.
- Collins, C.W. (1993a). A conference silence: Where are the debates on knowledge and personhood? Paper presented at invitational conference, *Creating our future: A curriculum for the 21st century* (Convenor : P.W. Hughes). Hobart, January.
- Collins, C.W. (1993b). *Approaching the history of education with a postmodern consciousness*. Paper presented at the annual meeting of the American Educational Research Association, Atlanta, GA. April.
- Comber, L.C. & Keeves, J.P. (1973). *Science education in nineteen countries*. New York: Wiley.

- Cooper, B. (1976). *Bernstein's codes: A classroom study*. Education Area Occasional Paper No. 8, Brighton: University of Sussex.
- Craig, J. & Harding, J. (Eds.) (1985). *Contributions to the third GASAT conference*. London: Centre for Educational Studies, King's College, University of London
- Daniels, H.R.J. (1988). An enquiry into different forms of special school organization, pedagogic practice and pupil discrimination. *C.O.R.E.* 12, 2.
- Daniels, J. & Kahle, J.B. (Eds.) (1987). *Contributions to the fourth GASAT conference*. Ann Arbor: The University of Michigan.
- Danzig, A.B. (1991). *Basil Bernstein's sociology of language: Deficit, difference and bewitchment*. Paper presented at the Annual Meeting, American Educational Research Association, Chicago, April.
- Danziger, K. (1973). Ideology and Utopia in South Africa: A methodological contribution to the sociology of knowledge. In G.W. Remmling (Ed.), *Towards the sociology of knowledge*. London: Routledge & Kegan Paul.
- Danzl-Tauer, L. (1990). *The relationship between intervention, equity and excellence in rural high school biology classrooms*. Unpublished doctoral dissertation, Purdue University, West Lafayette, IN.
- Davie, G. (1961). *The democratic intellect*. Edinburgh: Edinburgh University Press.
- Davies, Brian (1994). Durkheim and the sociology of education in Britain. *British Journal of Sociology of Education*, 15 (1), 3-25.
- Davies, Bronwyn (1989a). Education for sexism: A theoretical analysis of the sex/gender bias in education. *Educational Philosophy and Theory*, 21 (1), 1-19.
- Davies, Bronwyn (1989b). *Frogs and snails and feminist tales: Preschool children and gender*. Sydney: Allen & Unwyn.
- Dekkers, J., De Laeter, J. & Malone, J. (1991). *Science and mathematics enrolment patterns in Australia, 1970-1989*. Perth: Curtin University of Technology.
- Delamont, S. (1983). *Interaction in the classroom*. Second edition. London: Methuen.

- Denzin, N.K. (1988). *Triangulation*. In J.P. Keeves (Ed.), *Educational research, methodology and measurement: An international handbook* (pp. 511-513). Sydney: Pergamon.
- Dewey, J. (1958). *Experience and nature*. New York: Dover.
- Douglas, M. (Ed.) (1982). *Essays in the sociology of perception*. London: Routledge & Kegan Paul.
- Driver, R. (1988). A constructivist approach to curriculum development. In P.J. Fensham (Ed.), *Development and dilemmas in science education* (pp. 133-149). Lewes: Falmer Press.
- Driver, R. & Bell, B. (1986). Students' thinking and the learning of science: A constructivist view. *School Science Review*, 67, 443-456.
- Dynan, M.B., Parker, L.H. & Ryan, A.S. (1978). *Physical Science Evaluation Project Document RE/DPR/012*. Perth: Curtin University of Technology.
- Dynan, M.B., Parker, L.H. & Ryan, A.S. (1979). *Physical Science Evaluation Project, 1978*. Cooperative Research Series No.3. Perth: Education Department of Western Australia.
- Easley, B. (1986). The masculine image of science with special reference to physics: How much does gender really matter? In J. Harding (Ed.), *Perspectives on gender and science* (pp. 132-158). London: Falmer Press.
- Eccles, J. (1989). Bringing young women into math and science. In M. Crawford & M. Gentry (Eds.), *Gender and thought: Psychological perspectives*. New York: Springer-Verlag.
- Eccles, J., Adler, T.F., Futterman, R., Goff, S.B., Kaczala, C.M., Meece, J.L. & Midgley, C.M. (1983). Expectations, values and academic behaviours. In J.T. Spence (Ed.), *Achievement and achievement motives: Psychological and sociological approaches* (pp. 75-146). San Francisco: Freeman.
- Education Department of Western Australia. (1975). *Survey of upper secondary science education in Western Australia*. Curriculum Branch. Perth.
- Education Department of Western Australia. (1978). *An introduction to Physical Science*. Curriculum Branch. Perth.
- Eggleston, J. (1975). Conflicting curriculum decisions. *Educational Studies*, 1 (1), 6-15.

- Ellis, J.R. & Peterson, J.L. (1971). Effects of same sex organization on junior high school students' academic achievement, self-discipline, self-concept, sex role identification and attitude toward school. *Journal of Educational Research*, 64, 455-464.
- Erickson, E.L. & Erickson, L.J. (1984). Females and science achievement: Evidence, explanations and implications. *Science Education*, 68, 63-89.
- Fee, E. (1976). Science and the woman problem: Historical perspectives. In M. Teitelbaum (Ed.), *Sex differences: Social and biological perspectives* (pp. 175-223). Garden City, NY: Anchor Press.
- Fennema, E. & Leder, G. C. (Eds.) (1990). *Mathematics & gender*. New York: Teachers College Press.
- Fennema, E. & Peterson, P. (1985). Autonomous learning behavior: A possible explanation of gender-related differences in mathematics. In L.C. Wilkinson & C.B. Marrett (Eds.), *Gender-related differences in classroom interaction* (pp. 17-35). New York: Academic.
- Fennema, E. & Sherman, J.A. (1977). Sex-related differences in mathematics achievement, spatial visualization and affective factors. *American Educational Research Journal*, 14, 51-71.
- Fensham, P.J. (1985). Science for all: A reflective essay. *Journal of Curriculum Studies*, 17 (4), 415-435.
- Fensham, P.J. (1988a). Familiar but different: Some dilemmas and new directions in science education. In P.J. Fensham (Ed.), *Development and dilemmas in science education* (pp. 1-26). Lewes: Falmer Press.
- Fensham, P.J. (1988b). Physical Science, Society and Technology: A case study in the sociology of knowledge. *Australian Journal of Education*, 32 (3), 375-386.
- Finn, J.D. (1980). Sex differences in educational outcomes: A cross national study. *Sex Roles*, 6, 9-26.
- Finn, J.D., Dulberg, L. & Reis, J. (1979). Sex differences in educational attainment: A cross national perspective. *Harvard Educational Review*, 49, 477-503.
- Fleming, M.L. & Malone, M.R. (1983). The relationship of student characteristics and student performance in science as viewed by meta-analysis research. *Journal of Research in Science Teaching*, 20, 481-495.

- Forgasz, H.J. & Leder, G.C. (1991). To guess or not to guess: A question of risk. *Mathematics Competitions* 4(2), 58-69.
- Fowler, R. (1983). Sexually inclusive curriculum. *The Victorian Teacher*, 5, September, 12-17.
- Franzway, S. Court, D. & Connell, R.W. (1987). *Staking a claim: Feminism, bureaucracy and the State*. Sydney: Allen & Unwin.
- Fraser, B.J. (1990). Professional development activities of the National Key Centre for School Science and Mathematics. *South Pacific Journal of Teacher Education*, 18 (1), 65-74.
- Frye, M. (1983). *The politics of reality: Essays in feminist theory*. Trumansburg, NY: Crossing Press.
- Gaskell, P.J., McLaren, A., Oberg, A. & Eyre, L. (1993). *The 1990 British Columbia Mathematics Assessment: Gender issues in student choice in mathematics and science*. Vancouver, BC: Ministry of Education and Ministry Responsible for Multiculturalism and Human Rights.
- Gayford, C.G. (1986). Environmental education and the secondary school curriculum. *Journal of Curriculum Studies*, 18 (2), 147-157.
- Gerth, H.H. & Mills, C. Wright, (1948). *From Max Weber*. London: Routledge & Kegan Paul.
- Giaconia, R.M. & Hedges, L.V. (1985). Synthesis of teaching effectiveness research. In T. Husen & T.N. Postlethwaite (Eds), *The international encyclopaedia of education* (pp. 5100-5120). Oxford: Pergamon Press.
- Gianello, L. (1988). *Getting into gear*. Canberra: Curriculum Development Centre.
- Ginsberg, M.B. & Meyenn, R.J. (1979). Review of Lacey, C. (1979). "The socialization of teachers". *American Educational Research Journal*, Winter, 91-98.
- Ginzburg, R. (1989). Uncovering gynocentric science. In N. Tuana (Ed.), *Feminism and science* (pp. 69-84). Bloomington: Indiana University Press.
- Glass, G.V. (1977). Integrating findings: The meta-analysis of research. *Review of Research in Education*, 5, 351-379.
- Glennon, L.M. (1979). *Women and dualism*. London: Longman.

- Goodson, I. (1983). *School subjects and curriculum change*. London: Croom Helm.
- Goodson, I. (Ed.). (1985). *Social histories of the secondary curriculum: Subjects for study*. London: The Falmer Press.
- Goodson, I. (1992). Studying school subjects. *Curriculum Perspectives*, 12 (1), 23-26.
- Gould, S.J. (1981). *The mismeasure of man*. New York: W.W. Norton & Co.
- Granstam, I. & Frostfeldt, I. (Eds.) (1990). *Report book: European and Third World GASAT*. Jonkoping: University of Jonkoping.
- Gray, J.A. (1981). A biological basis for the sex differences in achievement in science? In A. Kelly (Ed.), *The missing half* (pp. 43-58). Manchester: Manchester University Press.
- Grosz, E.A. & de Lepervanche, M. (1988). Feminism and science. In B. Caine, E.A. Grosz & M. de Lepervanche (Eds.), *Crossing boundaries* (pp. 5-27). Sydney: Allen & Unwin.
- Gunstone, R.F. (1988). Learners in science education. In P.J. Fensham (Ed.), *Development and dilemmas in science education* (pp. 73-95). Lewes: Falmer Press.
- Haas, V. & Perrucci, C. (1984). *Women in scientific and engineering professions*. Ann Arbor: University of Michigan Press.
- Haggerty, S & Holmes, A (Eds.) (1993). *Transforming the curriculum: Our future depends on it*. Waterloo, Ontario: The University of Waterloo.
- Haladyna, T. & Shaughnessey, L. (1982). Attitudes towards science: A quantitative analysis. *Science Education*, 66, 547-563.
- Halsey, A.H., Floud, J. & Anderson, C.A. (1961). *Education, economy and society*. New York: The Free Press of Glencoe.
- Hanna, G. (1986). Sex differences in the mathematics achievement of eighth graders in Ontario. *Journal for Research in Mathematics Education*, 17, 231-237.
- Haraway, D. (1981). In the beginning was the word: The genesis of biological theory. *Signs*, 6 (3), 469-482.
- Harding, J. (1979). Sex differences in performance in examinations at 16+. *Physics Education*, 14, 280-284.

- Harding, J. (1985). Chemistry from issues. *McClintock Memos*, 5, 1-9.
- Harding, J. (1986). The making of a scientist. In J. Harding (Ed.), *Perspectives on gender and science* (pp.160-167). Lewes: The Falmer Press.
- Harding, J. (1991a). *A gender-inclusive curriculum*. Address delivered at Seminar, Science and Mathematics Education Centre, Curtin University of Technology, Perth, Western Australia. (Audiotape).
- Harding, J. (Ed.) (1991b). *Strategies in Action*. London: Equal Opportunities Commission.
- Harding, J. & Sutoris, M. (1984). *An object relations account of the differential involvement of boys and girls in science and technology*. Paper presented at IPN Symposium, Kiel, April.
- Harding, S. (1986). *The science question in feminism*. Ithaca: Cornell University Press.
- Harding, S. (Ed.) (1987). *Feminism and methodology: Social science issues*. Bloomington: Indiana University Press.
- Harding, S. (1989). Is there a feminist method? In N. Tuana (Ed.), *Feminism & science* (pp. 17-32). Bloomington: Indiana University Press. Reprinted from *Hypatia*, 2 (3).
- Harding, S. (1993). Rethinking standpoint epistemology: What is "strong objectivity"? In L. Alcoff & E. Potter (Eds.) *Feminist epistemologies* (pp. 49-82). New York: Routledge.
- Harding, S. & O'Barr, J. (Eds.) (1987). *Sex and scientific inquiry*. Chicago and London: The University of Chicago Press.
- Hargreaves, A. (1989). *Curriculum and assessment reform*. Milton Keynes: Open University Press.
- Hawke, R.J.L. & Jones, B.O. (1989). *Science and Technology for Australia*. Commonwealth of Australia: AGPS.
- Hawking, S.W. (1988). *A brief history of time*. London: Bantam Books.
- Head, J. (1980). A model to link personality characteristics to a preference for science. *European Journal of Science Education*, 2, 295-300.
- Head, J. (1985). *The personal response to science*. Cambridge: Cambridge University Press.

- Heldke, L. (1989). John Dewey and Evelyn Fox Keller: A shared epistemological tradition. In N. Tuana (Ed.), *Feminism and science* (pp. 104-115). Bloomington: Indiana University Press.
- Hextall, I. (1977). Marking work. In G. Whitty & M.F.D. Young (Eds.), *Explorations in the politics of school knowledge* (pp. 66-77). Driffield: Nafferton Books.
- Hextall, I. (1984). Rendering accounts: A critical analysis of the APU. In P.M. Broadfoot (Ed.), *Selection, certification and control* (pp. 245-262). Lewes: The Falmer Press.
- Hildebrand, G.M. & Allard, A. (1993). Transforming the curriculum through changing assessment practices. In S. Haggerty, & A. Holmes, *Transforming the curriculum: Our future depends on it* (pp. 255-263). Waterloo, Ontario: The University of Waterloo.
- Hornig, L. (1984). Professional women in transition. In V. Haas & C. Perrucci (Eds.), *Women in scientific and engineering professions* (pp. 43-58). Ann Arbor: University of Michigan Press.
- Hubbard, R. (1989). Science, facts and feminism. In N. Tuana (Ed.), *Feminism and science* (pp. 119-131). Bloomington: Indiana University Press.
- Hubbard, R. & Lowe, M. (Eds.) (1979). *Genes and gender II: Pitfalls in research on sex and gender*. New York: Gordian Press.
- International Association for the Evaluation of Educational Achievement (IEA). (1988). *Science achievement in seventeen countries: A preliminary report*. Oxford: Pergamon Press.
- Irigaray, L. (1989). Is the subject of science sexed? In N. Tuana (Ed.), *Feminism and science* (pp. 17-32). Bloomington: Indiana University Press. (Translated by Carol Mastroangelo Bove).
- Jackson, L.A. (1974). The myth of elaborated and restricted codes. *Higher Education Review*, 6 (2), 65-81.
- James, C. & Young, J. (1989). Case study: Equal opportunities through the Hertfordshire TVEI project. In H. Burchell & V. Millman (Eds.), *Changing perspectives on gender*. Milton Keynes: Open University Press.
- Johnson, R.T. & Johnson, D.W. (1987). Cooperative learning and the achievement and socialization crisis in science and math classrooms. In A.B. Champagne & L.E. Horning (Eds.), *Students and science learning*. Washington, DC: American Association for the Advancement of Science.

- Johnson, S. (1987). Gender differences in science: Parallels in interest, experience and performance. *International Journal of Science Education*, 9, 467-481.
- Johnston, J.E., Rennie, L.J. & Offer, J.A. (1993). Structural change in curriculum: The implications for equitable participation and achievement in mathematics. *Curriculum Perspectives*, 13 (1), 1-8.
- Jones, L.R., Mullis, I.V.S., Raizen, S.A., Weiss, I.R. & Weston, E.A. (1992). *The 1990 science report card: NAEP's assessment of fourth, eighth and twelfth graders*. Washington, DC: National Center for Educational Statistics.
- Jorg, T. & Wubbels, Th. (1987). Physics a problem for girls, or girls a problem for physics? *International Journal of Science Education*, 9 (3), 296-307.
- Jussim, L. (1990). Social reality and social problems: The role of expectancies. *Journal of Social Issues*, 46 (2), 9-34.
- Kahle, J.B. (Ed.) (1985). *Women in science: A report from the field*. Lewes: Falmer Press.
- Kahle, J.B. (1988). Gender and science education II. In P.J. Fensham (Ed.), *Development and dilemmas in science education* (pp. 1-26). Philadelphia: Falmer Press.
- Kahle, J.B. (1989). Images of scientists: Gender issues in science classrooms. In B.J. Fraser (Ed.), *Research implications for science teachers*, Volume 1, (pp.20-25). Perth: National Key Centre for School Science and Mathematics, Curtin University of Technology.
- Kahle, J.B. (1990). Real students take chemistry and physics. In K. Tobin, J.B. Kahle & B.J. Fraser (Eds.), *Windows into science classrooms: Problems associated with higher level cognitive learning* (pp. 92-134). New York: Falmer Press.
- Kahle, J.B., Anderson, A. & Damjanovic, A. (1991). A comparison of elementary teacher attitudes and skills in teaching science in Australia and the United States. *Research in Science Education*, 21, 208-216.
- Kahle, J.B. & Danzl-Tauer, L. (1991). The underutilized majority: The participation of women in science. In S.K. Majumdar, L.M. Rosenfeld, P.A. Rubba, E.W. Miller & R.F. Schmalz (Eds.), *Science education in the United States: Issues, crises and priorities*. Philadelphia, PA: Pennsylvania Academy of Science.

- Kahle, J.B. & Lakes, M.K. (1983). The myth of equality in science classrooms. *Journal of Research in Science Teaching*, 20, 131-140.
- Kahle, J.B. & Meece, J.L. (1992). Girls and science education: A developmental model. In D. Gabel (Ed.), *Handbook of research in science teaching and learning*. Washington DC: National Science Teachers Association.
- Kahle, J.B., Parker, L.H., Rennie, L.J. & Riley, D. (1993). Gender differences in science education: Building a model. *Educational Psychologist*, 28 (4), 379-404.
- Karabel, J. & Halsey, A.H. (Eds.) (1977). Educational research: A review and interpretation. In J. Karabel & A.H. Halsey, *Power and ideology in education* (pp. 1-85). Oxford: Oxford University Press.
- Keddie, N. (1971). Classroom knowledge. In M. Young (Ed.), *Knowledge and Control*. London: Collier Macmillan.
- Keeves, J.P. (Ed.) (1992). *The IEA study of science III*. Oxford: Pergamon Press.
- Keeves, J.P. & Kotte, D. (1992). Disparities between the sexes in science education 1970-84. In J.P. Keeves (Ed.), *The IEA study of science III* (pp. 141-164). Oxford: Pergamon Press.
- Keller, E.F. (1978). Gender and science. *Psychoanalysis and Contemporary Thought*, 1, 409-433. Reprinted in Keller, E.F. (1985). *Reflections on gender and science*. New Haven: Yale University Press.
- Keller, E.F. (1982). Feminism and science. *Signs*, 7 (3), 589-602.
- Keller, E.F. (1983). *A feeling for the organism: The life and work of Barbara McClintock*. New York: Freeman.
- Keller, E.F. (1985). *Reflections on gender and science*. New Haven: Yale University Press.
- Keller, E.F. (1989). The gender/science system: or, is sex to gender as nature is to science? In N. Tuana (Ed.), *Feminism and science* (pp. 33-44). Bloomington: Indiana University Press.
- Kelly, A. (1978). *Girls and science: An international study of sex differences in school achievement*. Stockholm: Almqvist & Wiksell.
- Kelly, A. (Ed.) (1981). *The missing half*. Manchester: Manchester University Press.

- Kelly, A. (1985). The construction of masculine science. *British Journal of Sociology of Education*, 6 (2), 133-145.
- Kelly, A. (Ed.). (1987). *Science for girls?* Milton Keynes: Open University Press.
- Kelly, A. (1988). Gender differences in teacher-pupil interactions: a meta-analytic review. *Research in Education*, 39, 133-154.
- Kelly, G.P. & Nihlen, A. (1982). Schooling and the reproduction of patriarchy: Unequal workloads, unequal rewards. In M.W. Apple (Ed.), *Cultural and economic reproduction in education* (pp. 162-180). London: Routledge & Kegan Paul.
- Kenway, J. (1990). *Gender and education policy: A call for new directions*. Geelong: Deakin University Press.
- Kenway, J., Willis, S., Blackmore, J. & Rennie, L.J. (in press). Making hope practical rather than despair convincing: Feminism, post-structuralism and educational change. *British Journal of Sociology of Education*.
- King, R. (1978). *All things bright and beautiful? A sociological study of infants' classrooms*. Chichester: Wiley.
- King, R. (1979). The search for the 'invisible' pedagogy. *Sociology*, 13, 445-448.
- Klainin, S., Fensham, P.J. & West, L. (1987). Activity based learning in chemistry. *International Journal of Science Education*, 9 (2), 217-227.
- Kliebard, H. (1986). *The struggle for the American curriculum 1983-1958*. Boston: Routledge.
- Kuhn, T. (1970). *The structure of scientific revolutions*. Second edition. Chicago: University of Chicago Press.
- Larabee, D. (1986). Curriculum, credentials and the middle-class: A case study of a nineteenth century high school. *Sociology of Education*, 59 (54), 42-57.
- Lather, P. (1988). Feminist perspectives on empowering research methodologies. *Women's Studies International Forum*, 11 (6), 569-581.
- Lather, P. (1991). *Feminist research in education: Within/against*. Geelong: Deakin University Press.

- Layton, D. (1972). Science as general education. *Trends in general education*, 25, 9-16.
- Layton, D. (1973). *Science for the people*. London: George Allen & Unwin Ltd.
- Leder, G.C. (1992). Mathematics and gender: Changing perspectives. In D.A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 597-622). New York: Macmillan.
- Lemke, J. (1994). *Postmodernism as a resource for science education?* Panel Discussion (with N.W. Brickhouse, S. Harding & R. Good), Annual Meeting, National Association for Research in Science Teaching, Los Angeles, March.
- Lewis, S. & Davies, A. (1988). *Gender equity in mathematics and science*. Canberra: Curriculum Development Centre.
- Lewontin, R., Rose, S. & Kamin, L. (1984). *Not in our genes: Biology, ideology and human nature*. New York: Pantheon Books.
- Lie, S. (Ed.) (1983). *Girls and science and technology: The second international GASAT conference*. Oslo: Institute of Physics, University of Oslo.
- Linn, M.C. & Hyde, J.S. (1989). Gender, mathematics and science. *Educational Researchers*, 18 (8), 17-27.
- Linn, R.L. (1973). Fair test use in selection. *Review of Educational Research*, 43, 139-161.
- Longino, H.E. (1989). Can there be a feminist science? In N. Tuana (Ed.), *Feminism and science* (pp. 45-57). Bloomington: Indiana University Press.
- Maccoby, E.E. & Jacklin, C.N. (1974). *The psychology of sex differences*. Stanford: Stanford University Press.
- MacCormack, C. & Strathern, M. (1980). *Nature, culture and gender*. Cambridge: Cambridge University Press.
- Mackinnon, D. (1976). Language and social class: An introduction to Bernstein's sociolinguistics. *E202 Schooling and society: The processes of selection*. London: The Open University.
- McKinnon, K. (1988). Developments in the curriculum and structures of upper secondary education in Australia: the last decade. *Journal of Curriculum Studies* 20, (6), 493-507.

- Maehr, M.L. (1983). On doing well in science: Why Johnny no longer excels; Why Sarah never did. In S.G. Paris, G.M. Olson & H.W. Stevenson (Eds.), *Learning and motivation in the classroom* (pp. 179-210). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Malcolm, C. (1989). Trends in school science curriculum and their implications for teacher education. In G. Speedy, C. Annice, P.J. Fensham & L. West (Eds.), *Discipline review of teacher education in mathematics and science*, Volume 3 (pp. 210-229). Canberra: Department of Employment, Education and Training.
- Malcom, S.M. (1976). *The double bind: The price of being a minority women in science*. Washington, DC: American Association for the Advancement of Science.
- Malcom, S.M. (1984). *Equity and excellence: Compatible goals*. Washington, DC: American Association for the Advancement of Science.
- Mallow, J.V. & Greenberg, S.L. (1982). Science anxiety: Causes and remedies. *Journal of College Science Teaching*, 11 (6), 356-358.
- Mannheim, K. (1936). *Ideology and Utopia*. London: Routledge and Kegan Paul.
- Maoldomhnaigh, K. & Hunt, A. (1988). Some factors affecting the image of the scientist drawn by older primary school pupils. *Research in Science and Technological Education*, 6, 159-166.
- Martin, J.R. (1982). Excluding women from the educational realm. *Harvard Educational Review*, 34 (4), 341-353.
- Martin, J.R. (1985). *Reclaiming a conversation: The ideal of the educated woman*. New Haven: Yale University Press.
- Mason, C.L., Kahle, J.B. & Gardner, A. (1991). Draw-a-Scientist test: Further implications. *School Science and Mathematics*, 91 (5), 193-198.
- Matyas, M.L. (1984). *Science career interests, attitudes, abilities and anxiety among secondary school students: The effects of gender, race/ethnicity and school type/location*. Paper presented at the Annual Meeting, National Association for Research in Science Teaching, New Orleans, April.
- Matyas, M.L. (1985). Factors affecting female interest in science and scientific careers. In J.B. Kahle (Ed.) *Women in science: A report from the field*. Philadelphia: Falmer Press.

- Mazzeo, J., Schmitt, A.P., & Bleistein, C.A. (1991, April). *Do women perform better, relative to men, on constructed-response tests or multiple-choice tests? Evidence from the Advanced Placement Examinations*. Paper presented at the annual meeting of the National Council of Measurement in Education, Chicago, Illinois.
- Mehrens, W.A. & Lehmann, I.J. (1969). *Standardized tests in education*. New York: Holt, Rinehart & Winston, Inc.
- Merton, R. K. (1957). *Social theory and social structure*. Chicago: Free Press of Glencoe.
- Merton, R.K. (1973). *The sociology of science: Theoretical and empirical investigations*. Chicago: University of Chicago Press.
- Meyer, M. & Koehler, M.S. (1990). Internal influences on gender and mathematics. In E. Fennema & G. Leder (Eds.), *Mathematics and gender* (pp. 60-95). New York: Teachers College Press.
- Morgan, E. (1972). *The descent of woman*. New York: Stein & Day.
- Moss, J.D. (1982). *Towards equity: Progress by girls in mathematics in Australian secondary schools*. Melbourne: Australian Council for Educational Research.
- Mullis, I.V.S. & Jenkins, L.B. (1988). *The science report card: Elements of risk and recovery*. Princeton NJ: Educational Testing Service.
- Murphy, P. (1988). Gender and assessment. *Curriculum*, 9, 165-171.
- Murphy, P. (1993). Equity and assessment. In S. Haggerty & A. Holmes, *Transforming the curriculum: Our future depends on it* (pp. 277-287). Waterloo, Ontario: The University of Waterloo.
- Murphy, R.J.L. (1982). Sex differences in objective test performance. *British Journal of Educational Psychology*, 52, 213-219.
- Nelson, B. Weiss, I. & Capper, J. (1990). *Science and mathematics education briefing book*. Washington DC: National Science Teaching Association.
- Nuttall, D.L., Backhouse, J.K., & Willmott, A.S. (1974). *Comparability of Standards Between Subjects*. (Schools Council Examinations Bulletin 29). London: Evans/Methuen Educational.
- O'Brien, M. (1981). *The politics of reproduction*. London: Routledge and Kegan Paul.

- O'Connor, D.J. (1957). *An introduction to the philosophy of education*. London: Routledge & Kegan Paul.
- Okebukola, P.A. (1985). The relative effectiveness of cooperative and competitive interaction techniques in strengthening students' performance in science classes. *Science Education*, 69, 501-509.
- Osborne, R. & Freyberg, P. (Eds.) (1985). *Learning in science: The implications of children's science*. Auckland: Heinemann.
- Ostrander, D. (1982). One-and two-dimensional models of the distribution of beliefs. In M. Douglas (Ed.), *Essays in the sociology of perception* (pp. 14-30). London: Routledge & Kegan Paul.
- Owens, L. & Barnes, J. (1982). The relationship between cooperative, competitive and individualized learning preferences and students' perceptions of classroom atmosphere. *American Educational Research Journal*, 19 (2), 182-200.
- Pallas, A.M. & Alexander, K.L. (1983). Sex differences in quantitative SAT performance: New evidence on the differential coursework hypothesis. *American Educational Research Journal*, 20 (2), 165-182.
- Parker, L.H. (1984). *Sex differences in mathematics: Trends in participation and achievement, 1976 - 1983*. Paper presented at the Annual Conference, Australian Association for Research in Education, Perth.
- Parker, L.H. (1987). The choice point – a critical event in the science education of males and females in Western Australia. In B.J. Fraser & G.J. Giddings (Eds.) *Gender issues in science education*. Perth: Curtin University of Technology.
- Parker, L.H. (1992a). *Curriculum renewal in upper secondary mathematics in Western Australia: A preliminary evaluation*. Perth: National Key Centre for School Science and Mathematics, Curtin University of Technology.
- Parker, L.H. (1992b). Sex differences in performance on external examinations and school-based assessment in science subjects. In F.Deshon (ed.) *Proceedings of the Seventeenth Annual Conference of the Western Australian Science Education Association*. Perth: Ministry of Education.
- Parker, L.H. (1993). Placing gender on the science teacher's agenda: A program for professional development. In P.A. Rubba, L.M. Campbell & T.M. Dana (Eds.), *Excellence in educating teachers of science* (1993 Yearbook of the Association for the Education of

Teachers in Science, pp. 203-220). Columbus OH: Clearing House for Science, Mathematics and Environmental Education, Ohio State University.

- Parker, L.H. Harding, J. & Rennie, L.J. (in press). Gender equity. In B.J. Fraser & H.J. Walberg (Eds.), *Improving science education: International perspectives*. Washington: National Society for the Study of Education.
- Parker, L.H. & Offer, J.A. (1987). School science achievement : Conditions for equality. *European Journal of Science Education*, 9, 263-269.
- Parker, L.H. & Rennie, L.J. (1989). Gender issues in science education with special reference to teacher education. In G.W. Speedy, C. Annice, P.J. Fensham & L.West (Eds.), *Discipline review of teacher education in mathematics and science* (Volume III) (pp.. 230-247). Canberra: Australian Government Publishing Service.
- Parker, L.H. & Rennie, L.J. (1992). *Constructivism and gender-inclusiveness: Has assessment kept pace?* Paper presented at the Annual Meeting, National Association for Research in Science Teaching, Boston, March.
- Parker, L.H. & Rennie, L.J. (1993). *Curriculum reform and gender-fair assessment.* Paper presented at the Annual Meeting, National Association for Research in Science Teaching, Atlanta, April.
- Parker, L.H. & Tims, J.E. (1993). *Sex differences in performance in external examinations and school-based assessment in Year 12 mathematics, Western Australia, 1987-1992.* Paper presented at the Annual Meeting, Australian Association for Research in Education, Perth, November.
- Popkewitz, T.S. (1994). *AERA position statement, Division B Vice-President.* Washington DC: American Educational Research Association.
- Popper, K. R. (1962). *The open society and its enemies, II.* London: Routledge & Kegan Paul.
- Pring, R. (1972). Knowledge out of control? *Education for Teaching*, Autumn, 23-46.
- Raat, J. Harding, J & Mottier, I. (Eds.) (1981). *Girls and science and technology. Congressbook GASAT conference 1981.* Eindhoven: Eindhoven University of Technology.

- Reid, I. (1978). *Sociological perspectives on school and education*. London: Open Books.
- Reid, W.A. (1985). The English sixth form in the nineteenth century. In I. Goodson (Ed.) *Social histories of the secondary curriculum: Subjects for study* (pp.289-312). London: The Falmer Press.
- Reimer, E. (1971). *School is dead*. Harmondsworth: Penguin Books Limited.
- Rennie, L.J. & Parker, L.H. (1991). Assessment of learning in science: The need to look closely at item characteristics. *Australian Science Teachers Journal*, 37 (4), 56-59.
- Rennie, L.J. & Parker, L.H. (1993). Assessment of learning in science: Further explorations of the implications of item context. *Australian Science Teachers Journal*, 39 (4), 28-32.
- Rennie, L.J. & Parker, L.H. (1993). Curriculum reform and choice of science: Consequences for balanced and equitable participation and achievement. *Journal of Research in Science Teaching*, 30 (9), 1017-1028.
- Rennie, L.J., Parker, L.H. & Hildebrand, G.M. (Eds.) (1991). *Action for equity: The second decade*. Perth: National Key Centre for Teaching and Research in School Science and Mathematics, Curtin University of Technology.
- Rennie, L.J., Parker, L.H. & Hutchinson, P.E. (1985). *The effect of inservice training on teacher attitudes and primary school science classroom climates*. Research Report No. 12. Perth: The University of Western Australia.
- Reyes, L.H. (1984). Affective variables and mathematics education. *The Elementary School Journal*, 84 (5), 558-582.
- Roe, A. (1952). *The making of a scientist*. Dodds Mead.
- Rose, P. (1985). *Writing on women: Essays in a renaissance*. Middletown, CT: Wesleyan University Press.
- Rosser, S.V. (1989). Feminist scholarship in the sciences: Where are we now and when can we ever expect a theoretical breakthrough? In N. Tuana (Ed.), *Feminism and science* (pp. 3-14). Bloomington: Indiana University Press.
- Rosser, M. (1982). *Women scientists in America*. Baltimore: The Johns Hopkins University Press.

- Rowntree, D. (1977). *Assessing students: How shall we know them?* London: Open University Press.
- Sayers, J. (1982). *Biological politics: Feminist and anti-feminist perspectives.* London: Tavistock.
- Saylor, J.G. & Alexander, W.M. (1974). *Planning curriculum for schools.* New York: Holt, Rinehart & Winston, Inc.
- Science Council of Canada. (1984). *Science for every student: Educating Canadians for tomorrow's world.* Ottawa: Science Council of Canada.
- Schau, C. & Scott, K.P. (1984). Impact of gender characteristics of instructional material: An integration of the research literature. *Journal of Educational Psychology*, 76 (2), 183-193.
- Scheuneman, J.D. & Gerritz, K. (1990). Using differential item functioning procedures to explore sources of item difficulty and group performance characteristics. *Journal of Educational Measurement*, 27, 109-131.
- Schibeci, R.A. (1986). Images of science and scientists and science education. *Science Education*, 76 (2), 139-149.
- Schibeci, R.A. & Sorensen, I. (1983). School children's perceptions of scientists. *School Science and Mathematics*, 83, 14-20.
- Schiebinger, L. (1987). The history and philosophy of women in science. *Signs; Journal of Women in Culture and Society*, 12 (2), 305-332.
- Schuster, M. & Van Dyne, S. (1984). Placing women in the liberal arts: Stages of curriculum transformation. *Harvard Educational Review*, 54 (4), 413-428.
- Scott, K.P. & Schau, C. (1985). Sex equity and sex bias in instructional materials. In S.S. Klein (Ed.), *Handbook for achieving sex equity through education.* Baltimore: The Johns Hopkins University Press.
- Sells, L. (1976). Images of science and scientists and science education. *Science Education*, 76 (2), 139-149.
- Selltiz, C., Jahoda, M. Deutsch, M. & Cook, S.W. (1965). *Research methods in social relations.* London: Methuen.
- Shapin, S. & Barnes, B. (1976). Science, nature and control: Interpreting Mechanics' Institutes. In R. Dale, G. Esland & M. MacDonald (Eds.)

- Schooling and capitalism* (pp. 55-65). London: Routledge & Kegan Paul.
- Sharp, R. (1980). *Knowledge, ideology and the politics of schooling*. London: Routledge & Kegan Paul.
- Sharp, R. & Green, A. (1975). *Education and social control*. London: Routledge & Kegan Paul.
- Shepardson, D.P. & Pizzini, E.L. (1992). Gender bias in female elementary teachers' perceptions of the scientific ability of students. *Science Education*, 76 (2), 147-153.
- Shymansky, J. A. & Kyle, W.C. (1992). Establishing a research agenda: Critical issues of science curriculum reform. *Journal of Research in Science Teaching*, 29 (8), 749-778.
- Silver, H. (1977). Nothing but the past, or nothing but the present? *Times Higher Educational Supplement*, 1 July.
- Sjoberg, S. & Imsen, G. (1988). Gender and science education I. In P.J. Fensham (Ed.), *Development and dilemmas in science education* (pp. 218-248). Lewes: Falmer Press.
- Smail, B. (1984). *Girl-friendly science: Avoiding sex bias in the curriculum*. York: Longman.
- Smail, B. & Kelly, A. (1984). Sex differences in science and technology among 11-year-old school children: II – affective. *Research in Science and Technological Education*, 2, 87-106.
- Smith, R. (1988). Extended review: Social analysis of education. *British Journal of Sociology of Education*, 9 (4), 489-492.
- Smith, W.S. (1987). COMETS: Evolution of a national women in science program. In J.Z. Daniels & J.B. Kahle (Eds.), *Contributions to the fourth GASAT conference* (Volume 2) (pp.335-342). Ann Arbor: The University of Michigan.
- Speedy, G., Annice, C., Fensham, P.J. & West, L. (1989). *Discipline review of teacher education in mathematics and science*. Canberra: Australian Government Publishing Service.
- Spender, D. (1980). *Man made language*. London: Routledge & Kegan Paul.
- Stage, E.K., Kreinberg, N. Eccles (Parsons), J. & Becker, J.R. (with others) (1985). Increasing the participation and achievement of girls and women in mathematics, science and engineering. In S.S. Klein

- (Ed), *Handbook for achieving sex equity through education* (pp. 237-268). Baltimore: Johns Hopkins University Press.
- Stark, W. (1958). *The Sociology of Knowledge*. London: Routledge and Kegan Paul.
- Steinkamp, M.W. & Maehr, M.L. (1983). Affect, ability and science achievement: A quantitative synthesis of correctional research. *Review of Educational Research*, 53, 369-396.
- Steinkamp, M.W. & Maehr, M.L. (1984). Gender differences in motivational orientations toward achievement in school science: A quantitative synthesis. *American Educational Research Journal*, 21, 39-59.
- Stubbs, M. (1983). *Language, schools and classrooms*. London: Methuen.
- Sydney-Smith, I. & Offer, J. (1991). What's happened to Biology in the 1980s? *SCIOS*, 26 (3), 7-17.
- Tomkins, G.S. (1986). *A common countenance: Stability and change in the Canadian curriculum*. Scarborough, Canada: Prentice Hall.
- Tuana, N. (1989) (Ed.), *Feminism and science*. Bloomington: Indiana University Press.
- Tyler, W. (1988). *School organisation: A sociological perspective*. London: Croom Helm.
- Van Dalen, D.B. (1979). *Understanding educational research: An introduction*. Fourth Edition. New York: McGraw-Hill Book Company.
- Vetter, B. (1984). Changing patterns of recruitment and employment. In V. Haas, & C. Perrucci (Eds.), *Women in scientific and engineering professions*. Ann Arbor: University of Michigan Press.
- Victorian Curriculum and Assessment Board (VCAB). (1989, 1990). *Report of Examiners: VCE (HSC) External Examinations: Physics*. Melbourne: Victorian Curriculum and Assessment Board.
- Walkerdine, V. (1989). Femininity as performance. *Oxford Review of Education*, 15 (3), 167-279.
- Weiner, G. & Arnot, M. (1987). Teachers and gender politics. In M. Arnot & G. Weiner (Eds.), *Gender and the politics of schooling* (pp. 352-364). London: Hutchinson and Open University.

- Weinreich-Haste, H. (1986). Brother sun sister moon: Does rationality overcome a dualistic world view? In J. Harding (Ed.), *Perspectives on gender and science* (pp. 111-131). Lewes: The Falmer Press.
- Western Australia. (1984a). *Education in Western Australia*. Report of the Committee of Inquiry into Education in Western Australia. (Chair: K.E. Beazley AO). Perth: Government Printer.
- Western Australia. (1984b). *Assessment in the upper secondary school in Western Australia*. Report of the Ministerial Working Party on School Certification and Tertiary Admissions Procedures. (Chair: Professor Barry McGaw). Perth: Government Printer.
- Western Australia. Board of Secondary Education (1977–1984). *Syllabus Manual(s)*. Perth: Board of Secondary Education.
- Western Australia. Board of Secondary Education (1977–1984). *Tertiary Admissions Examination (TAE) Papers, Biology, Chemistry, Human Biology, Physics, Physical Science*. Perth: Government Print.
- Western Australia. Ministry of Education. (1992). *Index of Disadvantage, Government Schools*. Confidential Document.
- Western Australia. Secondary Education Authority (1985–1993). *Minutes, SEA Meetings*. Perth: Secondary Education Authority.
- Western Australia. Secondary Education Authority (1985–1993). *Minutes, Tertiary Entrance Subject Committee*. Perth: Secondary Education Authority.
- Western Australia. Secondary Education Authority (1985–1993). *Minutes, Syllabus Committees for Biology, Chemistry, Human Biology, Physics, Physical Science*. Perth: Secondary Education Authority.
- Western Australia. Secondary Education Authority (1985–1993). *Syllabus Manual(s) Year 12*. Perth: Secondary Education Authority.
- Western Australia. Secondary Education Authority (1988). *Criteria defining a TEE subject*. Perth: Secondary Education Authority.
- Western Australia. Secondary Education Authority (1990). *Syllabus Manual Year 12*. Perth: Secondary Education Authority.
- Western Australia. Secondary Education Authority (1985–1993). *Tertiary Entrance Examination (TEE) Examination Papers, Biology, Chemistry, Human Biology, Physics, Physical Science*. Perth: Government Print.

- Wexler, P. (1987). *Social analysis of education: After the new sociology*. London: Routledge & Kegan Paul.
- Whitehouse, H. & Sullivan, M. (1992). *Girls and Year 12 science examinations*. Adelaide: Senior Secondary Assessment Board of South Australia.
- Whitty, G. (1977). *School knowledge and social control*. Milton Keynes: The Open University Press.
- Whitty, G. (1985). *Sociology and school knowledge*. London: Methuen.
- Whitty, G. & Young, M.F.D. (Eds.) (1976). *Explorations in the politics of school knowledge*. Driffield: Nafferton Books.
- Whyte, J. (1983). Non-sexist teachers: Evaluating what teachers can do to help girls opt in to science and technology. In S. Lie (Ed.), *Girls and Science and Technology, Conference Report* (pp. 309-318). Oslo: University of Oslo.
- Whyte, J. (1986). *Girls into science and technology: The story of a project*. London: Routledge & Kegan Paul.
- Wiersma, W. (1986). *Research methods in education*. Boston: Allyn & Bacon, Inc. Fourth Edition.
- Willis, S. (1989). 'Real girls don't do maths': *Gender and the construction of privilege*. Geelong: Deakin University.
- Willis, S. (1990). *Science and mathematics in the formative years: Papers presented at the second meeting of the Prime Minister's Science Council*. Canberra: Australian Government Publishing Service.
- Willmott, A.S. (1977). *CSE and GCE grading standards: The 1973 comparability study*. London: Macmillan Education.
- Wilson, V.L. (1983). The meta-analysis of the relationship between science achievement and science attitude: Kindergarten through college. *Journal of Research in Science Teaching*, 20, 839-850.
- Wood, R. (1978). Sex differences in answers to English Language Comprehension items. *Educational Studies*, 4, 157-165.
- Worrall, N. & Tsarna, H. (1987). Teachers' reported practices towards girls and boys in science and languages. *British Journal of Educational Psychology*, 57, 300-312.

- Yates, L. (1988). Does 'all students' include girls? A discussion of recent policy, practice and theory. *Australian Educational Researcher*, 15 (1), 41-57.
- Yates, L. (1990). *Theory/practice dilemmas: Gender, knowledge and education*. Geelong: Deakin University Press.
- Yates, L. (1991). *A tale full of sound and fury – signifying what? Feminism and curriculum policy in Australia*. Paper presented at the Annual Meeting, American Educational Research Association, Chicago, April.
- Yates, L. (1993). *The education of girls: Policy, research and the question of gender*. Melbourne: Australian Council for Educational Research.
- Young, M.F.D. (1971a). (Ed.). *Knowledge and control*. London, Collier Macmillan.
- Young, M.F.D. (1971b). An approach to the study of curricula as socially organized knowledge. In M. Young (Ed.), *Knowledge and control*. London, Collier Macmillan.
- Young, M.F.D. (1973). Educational theorizing: A radical alternative. *Education for Teaching*, 91, 7-11.
- Young, M.F.D. (1974). Notes for a sociology of science education. *Studies in Science Education*, 1, 31-40.
- Young, M.F.D. (1975). Curriculum change: Limits and possibilities. *Educational Studies*, 1 (2), 129-138, reprinted in M. Young & G. Whitty (Eds.) (1977). *Society, state and schooling*. Lewes: The Falmer Press.
- Young, M.F.D. (1976). The schooling of science. In G. Whitty & M.F.D. Young (Eds.) *Explorations in the politics of school knowledge* (pp. 47-61). Driffield: Nafferton Books.
- Young, M.F.D. (1977). School science - innovation or alienation? In P. Woods & M. Hammersley (Eds.) *School experience: Explorations in the sociology of education*. London: Croom Helm.