

**TOWARDS A NEW FRAMEWORK FOR  
RECONSTRUCTION OF THE  
PRIMARY SCIENCE CURRICULUM  
IN SOUTH AFRICA**

**BY**

**Carol Dianne Raubenheimer**

Submitted in partial fulfillment of the  
requirements for the degree of  
Master of Education,  
in the  
Department of Education,  
University of Natal,  
Durban  
1996

## **PREFACE**

The work documented in this thesis was undertaken by the author, under the supervision of Mr Mike Graham-Jolly.

The work represents original work by the author and has not been submitted in any form to another University. Where use was made of work done by others it has been duly acknowledged in the text.

## **ABSTRACT**

The purpose of this study is to ascertain, from a review and analysis of the literature, if any key messages emerge within which curriculum reconstruction of primary science education in South Africa can be undertaken.

Firstly, three paradigms in education are equated with three philosophies of science and the compatibility of modes of inquiry are highlighted. It is argued that paradigms can be used as a form of analysis to locate particular approaches to the teaching and learning of science.

Thereafter, an overview of major trends in science education is provided. The various views of and approaches to science education are analysed and located within particular paradigms. In order to assist in such analyses, a conceptual framework is developed. This draws on key determinants of curriculum development and locates these within each of the three paradigms.

The framework is applied to a review and analysis of international emphases in primary science education, within which five different perspectives are identified. These are located within different paradigms. Science education in developing countries is considered thereafter and some recent trends in primary science curriculum development in South Africa are examined. It is shown that the recent syllabus revision process and the revised

syllabuses in South Africa are still located in a technical approach to curriculum development.

In seeking an alternative approach, the weaknesses of imported ready made solutions from more developed contexts are highlighted, and an exploration of alternative approaches that are more responsive to local contexts is then undertaken. Some innovative examples of curriculum development in other parts of Africa and South Africa are examined.

From the review and analysis a set of key messages emerge for curriculum development in primary science education. In selecting appropriate programmes, it is vital that attention is given to children's' existing abilities and ideas, to the expected role for science in society, and to a particular society's values and norms. Material provision, of itself, does not bring about meaningful change, and teachers can and should be involved in the production of teaching materials. Another key message is that it is crucial for teachers to be involved in curriculum decision making, although they may need inservice support to make this possible. Approaches to inservice education must therefore give due consideration to this, and to developing classroom based teaching competencies. Finally, attention is given to some of the factors which may contribute to systemic change in science education.



## **ACKNOWLEDGEMENTS**

I wish to acknowledge the following:-

Mr Mike Graham-Jolly, Department of Education, University of Natal, Durban for support and advice given in supervising this work.

Professor Don Bedford, Physics Department, University of Natal, for reading and commenting on chapters two and three of the thesis.

The Centre for Science Development, for financial assistance in 1995.

My husband, Steven, for moral support for the duration of studies culminating in this work.

## LIST OF CONTENTS

	<b>Page</b>
<b>CHAPTER ONE: Introduction</b>	
1.1 Introduction to the problem being investigated	1
1.2 Scope and purpose of the study	4
<b>CHAPTER TWO: Paradigms in education and philosophies of science</b>	<b>8</b>
2.1 Introduction	8
2.2 Determinants of science and determinants of curriculum	9
2.2.1 Paradigms in science and in curriculum	11
2.2.2 Orientations	17
2.2.3 History in science and in curriculum	19
2.2.4 Politics in science and in curriculum	21
2.3 A closer view of paradigms in education and philosophies of science	24
2.3.1 Paradigms in education: An empirical-analytic paradigm	26

2.3.2 Philosophies of science: Logical positivism	28
2.3.3 Paradigms in education: A symbolic science paradigm	31
2.3.4 Philosophies of science: Wholism	35
2.3.5 Paradigms in education: A critical sciences paradigm	38
2.3.6 Philosophies of science: Marxism and neo-Marxism	43
2.3.7 Concluding discussion	45
<b>CHAPTER THREE: Trends in science education</b>	<b>50</b>
3.1 Introduction	50
3.2 Paradigms as a framework for theoretical analysis in education	50
3.3 Curriculum emphases in science education	53
3.4 Research perspectives in science education	57
3.5 Approaches to science teaching and learning	66
3.6 Priorities in science education	68
3.7 Dominant concerns of three curriculum orientations	70
3.8 Paradigms in the classroom	73
3.9 Developing a framework for analysis	75

<b>CHAPTER FOUR: International emphases in primary science education</b>	<b>78</b>
4.1 Introduction	78
4.2 A content emphasis	78
4.3 A doing and seeing emphasis	79
4.4 A process skills emphasis	81
4.5 A conceptual change approach	92
4.6 A concept/process based science	106
4.7 Concluding remarks	111
<b>CHAPTER FIVE: Primary science education in South Africa and in other developing contexts</b>	<b>112</b>
5.1 Introduction	112
5.2 Recent practices of curriculum reform in South Africa	113
5.3 Some trends in curriculum development in developing countries	124
5.4 Selection of appropriate content	132
5.5 Materials development and resourcing the curriculum	139
5.6 Teacher participation in curriculum development	146
5.7 Inservice education of teachers	151
5.8 Models of systemic change	157
5.9 Concluding remarks	164
<b>REFERENCES</b>	<b>166</b>

## LIST OF TABLES

	<b>Page</b>
Table 1: Four paradigm model of society	14
Table 2: A description of three paradigms with respect to interest and main focus	16
Table 3: Dominant concerns of three curriculum orientations	72
Table 4: Views of teaching and learning within different paradigms	77
Table 5: A comparison of the science and literacy process skills	89

## **LIST OF FIGURES**

	<b>Page</b>
Figure 1: The conceptual structure of the document	7

## CHAPTER ONE

### INTRODUCTION

#### 1.1 Introduction to the problem being investigated

South Africa is in a state of transition from an apartheid era to one in which principles of democracy are set to transform the fabric of society. The new Government of National Unity has also been tasked with the function of reconstructing the system of education. One of the first jobs was to amalgamate the racially segregated departments of education and to generate policy to facilitate educational improvement. The publication of the White Paper in March 1995 (Republic of South Africa, 1995) can be seen as a move towards setting in place enabling policy for educational change. The document is underpinned by a set of values and principles which argue for the democratic right of all to quality education and which sets the scene for redress and fundamental reconstruction in education. A key area in which change is seen as essential is that of curriculum development, with an emphasis on science and mathematics education (Republic of South Africa, 1995).

Historically, science education in South Africa has been driven by a highly technicist and traditional view of science (Kahn *et al*, 1992) in which facts, content and the re-discovery of knowledge by doing experiments have been emphasised. This is reflected in curriculum

documents and in teaching and learning situations, particularly in Black schools. Science as a form of problem solving and inquiry has been non-existent, as a result of a deliberate policy of actively discouraging critical thinking.

Access to a reasonable quality of science education was limited to a minority of students, mostly white. Science and mathematics education in Black schools was characteristically of an inferior standard, with inadequate infrastructural provision (e.g. laboratories, equipment, textbooks and written materials). Also, teachers in Black schools tend to be underqualified and ill prepared to teach the subject, thereby perpetuating a didactic and content driven approach to the teaching of science. This has resulted in a 'cycle of mediocrity' (African National Congress, 1994, p 83) because 'teachers who are poorly prepared and underqualified typically produce weak and poorly prepared school students'.

The reason for the inadequate provision for science education in Black schools may be attributed to the fact that Black pupils were being prepared for other more subservient roles in society. Access to technological knowledge is a political issue, because those with such knowledge would be more likely to retain power. So, in South Africa the emphasis of scientific and technological development was on serving 'the needs of the state security, and the suppression of the majority of the population' (International Development Research Centre, 1993, p4), as evidenced by the size of the budget spent on defence and nuclear programmes. Thus, the previous South African government felt that Blacks should not have access to technological expertise, as this would have placed them in a more



powerful position than was perceived to be desirable. As a result, only one in five Black students selects physical science or mathematics at senior secondary school level (Republic of South Africa, 1995) and the performance levels in the matriculation examinations, of those taking these subjects, is abysmally low (Rollnick and Reddy, 1995). The consequence is that South Africa has a very low proportion of skilled labour (24%) and this compares unfavourably with the international norm (60%). In 1993, of the skilled labour, only 1,7% of the economically active population were in scientific and engineering positions and of this figure, only 3% were Black (Department of Arts, Culture, Science and Technology, 1996). ‘This was one of the many consequences of the human resource development strategies of the apartheid government’ (Department of Arts, Culture, Science and Technology, 1996, p 78). Thus, the workforce participation rates in scientific and engineering fields compare very unfavourably with countries with comparable economic levels, and particularly with countries with more advanced economies.

Science education in the primary school is an important precursor for adequate science education at the secondary school level. It is during primary schooling that a basis for the subsequent learning of science is established, that key foundation concepts are formed, that attitudes to science are established and that pupils gain an understanding of the methods of doing science. These are consolidated in the secondary phase. Therefore, curriculum development for science education must commence with the consideration of primary school science education.

It is against this backdrop that curriculum reform in science education must be viewed. The problems created by historically discriminatory practices must be given due attention and mechanisms for redress introduced. In South Africa the context for change now exists and so research, proposals and recommendations are needed to guide the direction of curriculum development in science education. It is within this framework that this study has acquired a greater urgency.

## **1.2 Scope and purpose of the study**

The intention of this research is to generate a set of key messages, to be used to guide policy and action in curriculum development in primary science education in South Africa. These key messages are theoretically grounded in paradigms in education, in the dominant international perspectives on science education, in the major international emphases in primary science education, and in the reported experiences from other developing contexts.

The methodology employed in the study is that of:-

- reviews of the literature in key areas of concern,
- the development of a framework for analysis,
- conducting documentary analyses by applying the framework.

In the following paragraphs an overview of the structure of the thesis is provided as an advanced organiser for the reader. This conceptual structure is shown in figure 1.

In chapter two, the nature of science from different philosophical perspectives is examined and related to three possible paradigms in the social sciences, which includes education. Some of the parallels between philosophies of science and paradigms in education, including modes of inquiry, are then explored and related to one another. It becomes clear that the dominant scientific paradigm has infused into modes of inquiry in social sciences and practices in education. Alternative paradigms have not been adequately explored in the sciences, and this has had an impact on the practice of science education.

In chapter three it is argued that paradigms can be used in the analysis of trends in science education. A review of the main international trends, emphases and research perspectives in science education is undertaken and through documentary analysis these are located within different paradigms in education. Thereafter, a comprehensive theoretical framework, for the analysis of science education, is developed and detailed in tabular format. This framework draws on some of the key determinants of education (e.g. view of knowledge, view of the purpose of education, view of the learner, teaching methods) and elaborates these within three different paradigms.

In chapter four a review of the literature reveals five major emphases in primary science education. These emphases are further analysed and located within particular paradigms, by applying the theoretical framework developed in the previous chapter. Key lessons from primary science education internationally are also described, in order to incorporate these into the key messages proposed in the next chapter.

In the final chapter, a documentary analysis of the recent primary science syllabuses in South Africa is conducted. The analysis uses the analytic framework developed in chapter three. Thereafter, major trends in science education in other developing contexts, particularly in Africa, are also reviewed and analysed. Examples of innovations that challenge the dominant paradigm are detailed. From these analyses a set of key messages is derived for curriculum reconstruction in the context of South Africa. It is recommended that these key messages be considered as the basis for further curriculum development, including the establishment of appropriate decision making processes, within primary science education.

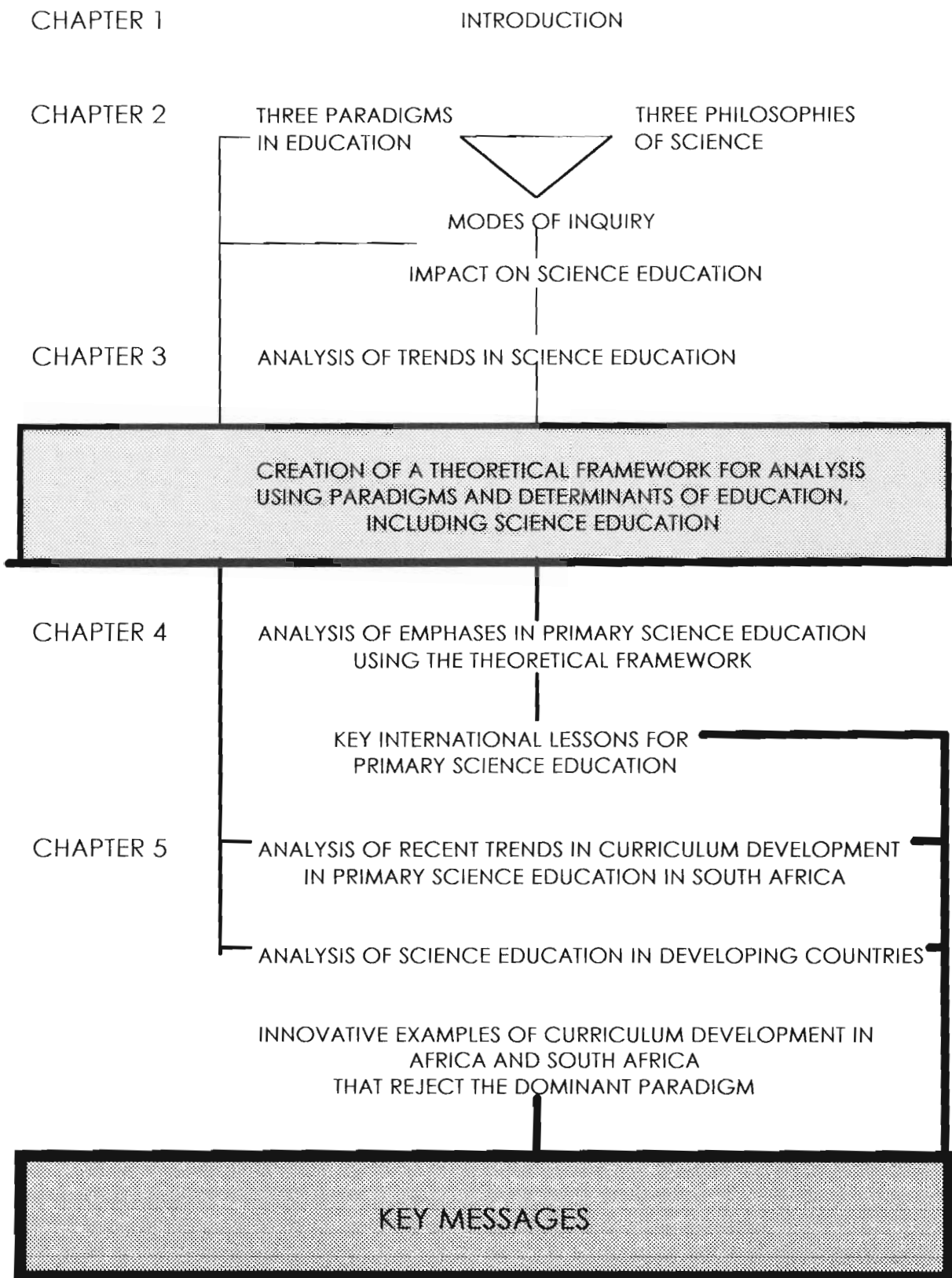


Figure 1: The Conceptual structure of the document

## CHAPTER TWO

### PARADIGMS IN EDUCATION AND PHILOSOPHIES OF SCIENCE

#### 2.1 Introduction

‘At the heart of this debate is the question of whether the curriculum field can continue to pattern itself after the model of the natural sciences.’

Giroux, 1981, p 11

It is widely recognised that any curriculum is embedded in a social, historical, political and economic context (Young, 1971; Giroux *et al*, 1981; Cornbleth, 1990, Goodson, 1990; 1994). This has led to a strong critique of the historical reliance of curriculum developers upon traditional approaches to curriculum development. Giroux *et al* (1981) referred to those who have subjected the curriculum field to critique, the reconceptualists. The re-conceptualists emphasised that curriculum is neither neutral nor objective, but is directly informed and driven by contextual considerations. Central to this is ‘the recognition that power, knowledge, ideology, and schooling are linked in ever changing patterns of complexity’ (Giroux, 1981, p 18). These concerns have led to a reconsideration of the nature and purposes of education.

Similarly, the practice of science has received considerable critique from sociologists and historians

studying the nature of scientific investigations and the structure of scientific knowledge. Some authors (Stockman, 1983; Aronowitz, 1988) are critical of the 'truth' claims made by science and highlight alternative frameworks for the creation and interpretation of knowledge. A recurrent theme in these critiques is the relationship between knowledge and power and the way in which science informs and directs society and visa versa;- that is, the political nature of science (Rouse, 1987, Aronowitz, 1988; Fisher, 1990; Proctor, 1991). For instance, Cozzens and Gieryn (1990) emphasise the term 'science in society' rather than 'science and society' as the latter infers that the two are mutually separable. Embedded in this is an acknowledgement that science is not a neutral process and that values and underpinning assumptions inform and direct the practice of science (Longino, 1990; Proctor, 1991). These authors call for an acknowledgement and reconsideration of the status given to the role played by science in society.

There are parallels in the critique of curriculum development and in the critique of the practice of science. The practice of both curriculum development and of science can be said to be located within and driven by a particular social, historical, political and economic context. The values and power relations that are implicit in a particular context lead to particular forms of practice. Knowledge therefore cannot be neutral.

## **2.2 Determinants of science and determinants of curriculum**

In an analysis of major textbooks used in courses on curriculum in the USA, Rogan and Luckowski (1990) identify four main elements that are emphasised. These are:-

paradigms,  
curriculum orientations,  
history and  
politics.

These elements are useful for the analysis of curriculum and of scientific practice. They can be termed major determinants because they contribute to determining the way in which curriculum and science are perceived and practised. Each of these will be briefly described in order to gain clarity on their meaning in the fields of curriculum and of science.

Other determinants have been articulated by Hass (1983). These include values and goals, social forces, view of human development, view of the nature of learning, view of the nature of knowledge and cognition; and view of the learner. Some of these determinants will be used in chapter three (p 77) in order to develop a framework for analysis. These determinants will also be implicitly discussed in this chapter where different paradigms are compared and contrasted with respect to ontology, epistemology and methodology. For instance, in considering epistemology, views on the nature of learning and the nature of knowledge and cognition will be implicitly covered. Different determinants are therefore inextricably linked and it is questionable whether they can be isolated from each other.

Determinants are embedded in a particular social context and ideological stance which determine the views adopted by individuals and society. By accepting the particular determinants outlined, the author is acknowledging a particular bias. This bias is that knowledge is a social construct embedded in particular social and political contexts which reflect particular views and approaches



to education and science.

### **2.2.1 Paradigms in science and in curriculum**

The relationship between education and science is intricate and interconnected. Nel (1989) argued that theories and methods in the social sciences, which includes education and the field of curriculum, have been modelled on the natural sciences. Thus, we can say that paradigms in the social sciences, including education, have arisen out of paradigms in the natural sciences.

A paradigm in its simplest form can be described as a set of values, perceptions, thoughts and beliefs that 'form a particular view of reality' (Capra, 1983, p 11). These views may be held either consciously or subconsciously, but nevertheless direct action. A paradigm shift entails a re-examination and rejection of old beliefs and an acceptance of a new set of values to inform action. Clearly, the underlying values and assumptions that inform a particular paradigm are important determinants of both science and the curriculum.

Thomas Kuhn (1970) used the term paradigm as a form of analysis of the practice of science. He suggested that science undergoes cyclical patterns of normal science, crisis and revolution. The phase of 'normal science' embodies a model from which 'coherent traditions of research' (p 10) arise and typically scientists adopt an uncritical view of their work. This model includes the conceptual framework, methods and procedures through which a group of researchers operate (Carr and Kemmis, 1986). This becomes the dominant research paradigm and is underpinned by a set of values and beliefs that determine the way that the world is viewed and interacted with.

However, from time to time, anomalies and findings that cannot be explained within the dominant paradigm arise. This leads to a period of crisis in which new explanations are sought. The crisis necessitates that the researchers engage in fundamental debate about the nature of their research and the values and procedures underpinning the particular paradigm they are located within. When there is sufficient dissent with the old paradigm, a 'scientific revolution' occurs and this amounts to a conversion of the scientific community to a new paradigm. Kuhn notes that there have been several such paradigm shifts during the history of science.

Jarvie (1983) is critical of Kuhn's notion of paradigms as monolithic, dominant 'positions' that exist for a certain period of time and which allow for the practice of 'normal' research. He suggests that whilst this may be true of the natural sciences it is certainly untrue of the social sciences where there exist a multiplicity of paradigms driving research. Kuhn's view of paradigm also seems to be more concerned with the methodological procedures and languages of discourse in the natural sciences, rather than an examination of more fundamental questions relating to ontology and epistemology. Thus, Kuhn's use of paradigm is different to the way it is used in social sciences as he did not primarily concern himself with ontological and epistemological assumptions.

This may, however, be an oversight by historians and philosophers who have studied the work of Kuhn. Rouse (1987) argued that the practical aspects of Kuhn's work have been almost 'universally overlooked' (p xii) and that a recovery of the practical dimension of Kuhn's work would provide for a more systematic treatment of science as a practical activity. In this regard, practical must be read in the sense of Schwab (1970, in Schubert, 1986) and those concerned with an interpretative approach to investigation.

In educational inquiry the dominant paradigm has been a traditional approach to education (Giroux, 1981). The traditionalist view is premised on the notion of functionalism which advocates that curriculum is the sum of the courses offered in a school. This approach to curriculum is based upon 'competitiveness, individualism and authoritarianism' (Leriche, 1990, p 62) and assumes that there is a fixed body of knowledge to be acquired in a structured and sequential manner. It is also premised on the traditional natural science view of the world. Giroux (1981) notes that the traditional curriculum paradigm directs action but does not take into consideration the needs of the individual nor the broader needs and context of society. He called for a new paradigm for curriculum inquiry.

Jarvie (1983) noted that there are several competing philosophies of the social sciences, leading to healthy debate amongst those in the field as to the nature and purpose of sociological inquiry. Thus, Hassard (1993) writes that several sociologists have attempted to define and categorise paradigms and one author (Effrat, 1973, cited in Hassard, 1993) argued for 8 distinct paradigms. Burrell and Morgan (1979, cited in Hassard, 1993) suggested four different paradigms for the analysis of organisations, namely a functionalist paradigm, an interpretive paradigm, a radical humanist paradigm and a radical structuralist paradigm. Hassard (1993) presents this as a matrix of four paradigms and this is replicated in table 1.

Table 1: Four paradigm model of social theory

### THE SOCIOLOGY OF RADICAL CHANGE

	<b>Radical Humanist</b>	<b>Radical Structuralist</b>	
<b>Subjective</b>	<b>Interpretive</b>	<b>Functionalist</b>	<b>Objective</b>

### THE SOCIOLOGY OF REGULATION

(from Burrell and Morgan, 1979, cited in Hassard, 1993, p 66).

The paradigms are represented on a matrix that ‘intersect subject-object debates in the theory of social science with the consensus-conflict debates in the theory of society’ (Hassard, 1993, p 66).

Thus, the functionalist paradigm is based on the notion that society is real and concrete and is directed to the production and maintenance of order and regulation.

The interpretive paradigm also seeks regulation of society through the generation of consensus via intersubjective agreement. However, within this paradigm, the social world is ‘best understood

from the viewpoint of the participant-in -action' (Hassard, 1993, p 89) and so it is assumed that there is no real external world, but one that is interpreted through experience and discourse. Within the radical humanist paradigm the view is also adopted that there is no objective, external reality. However, 'social construction is tied to a pathology of consciousness' (p 89) in which the actors find themselves locked into the social world they have created. Thus, the radical humanist seeks to highlight the aspects of society that are alienating, in order to bring about radical social change. Within the radical structuralist paradigm, an objective, realist view of the social world is accepted. The social scientist operating within this paradigm seeks to highlight the contradictions and tensions evident in society in order to bring about transformation of the whole social system.

It is more commonly agreed that there are three distinct perspectives within sociology, namely logical empiricism or functionalism; interpretive theories or symbolic interactionism; and critical theory or conflict theory (Soltis, 1984 and Leriche, 1990, respectively). Thus, several educationists including Popkewitz (1984) and Grundy (1987) have identified three main competing paradigms or perspectives which determine what and how educational inquiry is undertaken. These are an empirical-analytic paradigm, a symbolic sciences paradigm and a critical sciences paradigm (Popkewitz, 1984). Grundy (1987), after Habermas, describes three knowledge constitutive or cognitive interests. These are a technical interest, a practical interest and an emancipatory interest, with each interest corresponding respectively to the three paradigms outlined by Popkewitz (1984). Based on these works, table 2 has been constructed to highlight the basic premises of these three paradigms and interests.

Table 2: A description of three paradigms with respect to interest and main focus

PARADIGM	INTEREST	MAIN FOCUS
Empirical-analytic	Technical	<ul style="list-style-type: none"> <li>• The use of procedural knowledge for testing, validating and rejecting hypotheses about observable events.</li> <li>• The generation of technical, expert and neutral knowledge.</li> <li>• The search for lawlike regularities and generalisations (truth).</li> </ul>
Symbolic sciences	Practical	<ul style="list-style-type: none"> <li>• The interpretation of reality through reflection.</li> <li>• The identification of rules that make up and govern society.</li> <li>• The generation of meaning and understanding through dialogue and discourse and negotiation.</li> </ul>
Critical science	Critical	<ul style="list-style-type: none"> <li>• The identification of constraints, assumptions and myths.</li> <li>• The understanding of the relationship between value, interest and action (i.e. to understand social conditions that restrict our lives).</li> <li>• To change the world (i.e. act on it and not describe it).</li> </ul>

Each paradigm offers a different way of viewing and approaching the world. Thus, inquiry and the analysis of social phenomena within each paradigm is approached from a fundamentally different perspective. This means that distinctly different concepts, methods and analytic tools are used within each paradigm.

In order to distinguish between the different paradigms, Guba (1990) suggests a way to categorise competing paradigms by examining their underpinning assumptions. He suggests that competing paradigms can be distinguished on the basis of their underlying ontology, epistemology and methodology. Hassard (1993) adds a fourth criterion, that of human nature.

For the purposes of this study the paradigms described by Popkewitz (1984) will be used as they provide three distinct categories which have informed educational inquiry. In addition, the concepts of ontology, epistemology and methodology, suggested by Guba (1990), will be applied to each paradigm. These concepts give insights to the view of reality and the view of knowledge that drives educational inquiry and the appropriate methods for each paradigm.

### **2.2.2 Orientations**

Rogan and Luckowski (1990) note that there are two ways in which the term curriculum orientation is used in the books they surveyed. The dominant meaning is that of the purposes served by the curriculum and some examples are:-social reconstruction, technological, academic and humanistic (McNeil, 1985, cited in Rogan and Luckowski, 1990). They note that different authors use very different terms to outline the purposes of education which makes comparison and any kind of consensus somewhat difficult. They suggest that this is in part due to the particular bias

of individual authors who tend to favour and promote one orientation over others. The second way in which orientation is used is to define curriculum. An example given is 'the cumulative tradition of organised knowledge' (p 22), which will have a particular epistemological bias.

Returning to orientation as purposes of education, Millar and Seller (1985) suggest that there are three dominant orientations that determine the purpose of education. These are transmission, transaction and transformation.

The transmission orientation has as its purpose the transmission of 'a selected segment of knowledge' (p 30). The dissemination of academic information and its acquisition are key concerns. This orientation can be related to an empirical analytic paradigm where facts and a fixed body of knowledge are accepted.

A transactional orientation is described as a 'dialogue between the student and the curriculum in which the student reconstructs knowledge through the dialogue process' (p 33). There is an emphasis on reflection, active learning and problem solving skills. This reflects a hermeneutic process which is synonymous with a symbolic sciences paradigm.

A transformational orientation focuses on 'personal and social change' (p 37). The purpose is to identify problems and issues and through the process of active involvement with that issue undergo some personal change (knowledge, attitude, behaviour) or bring about some change in society. This is compatible with a critical sciences paradigm within which the aim of social inquiry is to change society and not just to describe or understand it.



Thus, it can be suggested that the different curriculum orientations outlined by Millar and Seller are embedded within particular theories of reality and knowledge construction (paradigms), and that these determine the purposes outlined for education. Using this analysis as the basis, the major orientations, emphases, research perspectives, priorities and approaches in science education are related to particular paradigms in chapter 3.

### **2.2.3 History in science and in curriculum**

The consideration of modes of inquiry in science and in education would not be complete without a brief consideration of the historical and political elements. In the introduction it was argued that both education and science are embedded in particular social contexts. These contexts have historical and political dimensions.

For instance, consideration of the history of science led Kuhn (1970) to articulate his views about normal science and scientific revolutions. He documents several instances throughout the history of science where such scientific revolutions have occurred and notes their implications for the way in which science was subsequently conceived and practised. Thus, Atkin and Helms (1993) note that science is influenced by the people who do it and by the concerns and issues of the historic period in which it is practised.

Similarly, Proctor (1991) conducts a historical analysis of how the notion of value-free science arose, the roots of which extend back to the time of Plato who believed that contemplative thought was superior to practical action. This separation of theory and practice has remained as a central element in the practice of so called neutral science. During the history of science this was extended

to exclude the role of morals in investigation, to include the notion of a universe devoid of purpose (the Cartesian split between mind and matter), and to promote the idea that values are subjective and can therefore have no part to play in discovering the 'truth' (Proctor, 1991). Whilst many of these notions have been overturned in recent years with the recognition that knowledge is provisional, that facts are theory-laden and that knowledge is contextual, the practice of science has often remained static, using established and unquestioned methods in search of value neutrality.

Proctor (1991) notes that a historical analysis of science should not remain in the realm of history as a series of events, but should rather be a critical account and interpretation of those events. History should not only speak to the past, but should also relate to contemporary issues and problems in current studies.

Similarly, Reid (1992) and Goodson (1994) also called for a deeper and richer 'historiography' of the field of curriculum inquiry in order to interpret main trends and issues. Again this indicates parallels between the fields of education (including curriculum) and science.

Knowledge of the history of the field of curriculum is important for understanding the main trends and issues that have emerged in the last forty years or so. Thus, Reid (1992) provides an overview of the state of curriculum inquiry and highlights some of the current issues in the field. He concludes that 'those interested in curriculum inquiry should, in the 1990's, be taking stock of what the work of the last 20 years has achieved, and what it has failed to achieve' (p 176). He also argues that such a study of the history of curriculum inquiry, if combined with an understanding of current trends, might lead to a 'reconceived tradition of curriculum inquiry' (ibid).

A review of the history of the field can prevent practitioners, researchers and theorists from falling into the pitfalls of the past and could give direction for the consolidation of existing practices and theories. To this end Goodson (1990, 1994) calls for the collection of cases that detail the personal histories of teachers and the histories of the social construction of the written curriculum (syllabuses, textbooks, course outlines, etc) because these are examples of the social invention of tradition. He suggests that historical analysis of this sort will highlight ways in which education and schooling have served to perpetuate dominant ideologies and will provide evidence of ‘ the human process by which men make their own history’ (Goodson, 1990, 307) and of the factors that prevent people from creating their own history. It is important that we understand these forces if we are to move towards new modes of curriculum inquiry and practice.

Whilst an understanding of curriculum history and history of science are acknowledged as important determinants, a deeper analysis of this falls beyond the scope of this piece of work.

#### **2.2.4 Politics in science and in curriculum**

The practice of science has been acknowledge to have political ramifications (Rouse, 1987, Aronowitz, 1988; Fisher, 1990; Proctor, 1991).

This includes the criticism of science as hegemony serving its own ends (Aronowitz, 1988). This can be seen in the dominant discourses and the ways in which students are inducted into the discipline, learning the tools of the trade. Aronowitz (1988) goes on to highlight the challenges from three different quarters that have been posed to science in the last thirty years. These include the challenge from religious groups who demand an equal place in the curriculum and the

introduction of teleology into the study of science. The second challenge comes from social ecologists who contend that science propagates domination over nature, thereby giving legitimacy to state and capitalist exploitation of natural resources. The practices of science as hegemony has been responsible for large scale ecological disasters. The social ecologists argue against neutrality of science because it is integrally linked to ethics and moral judgements. The third challenge has arisen from feminist critiques of science where the hegemony and myths associated with science have served to deny the entry and acceptance of women into the field. For instance, Longino (1990) in her analysis of the alleged sex differences in temperament, behaviour and cognitive ability shows how ideologies about gender serve to structure the conclusions and evidential relationships.

Aronowitz (1988) and Proctor (1991) highlight ways in which science has often served overtly political functions, like the 'Aryan' science of Nazi Germany and the attempts to legitimate supposed cognitive differences on the basis of race and gender. They also expose the manner in which science serves dominant interests, like war, industry and capital, largely through funding programmes. What research is undertaken is currently largely framed by national priorities and available funding. These are all political roles for science as they serve dominant interests and promote particular values.

Proctor (1991) goes on to argue that the political nature of science needs to be seen in its context and must not be confused with the epistemological question of whether or not science is neutral. Rather, we need a political philosophy of science that 'focuses on the forms of power in and around science' (p 13). Thus, the important question becomes a political one of why do we know what we know and why do we not know what we don't know?

The political role of education has also been recognised. For instance, Leriche (1990) notes that Tyler was acutely aware of the political role that education can play in society when he stated that school curricula have only two options. The choice was between the development of young people to fit into society or the development of young people who seek to improve society. However, Tyler chose the first option, reducing education to a set of procedures and objectives to be met through instruction. The choice was the control of individuals in order to maintain stasis in society.

Education is therefore essentially a political process for many reasons. Education operates within the historical constructs of institutions and traditional authority structures. These lend credibility to certain styles of educational practice with particular emphases. Those in power are often able to ratify or deny suggestions and proposals from those lower in the hierarchical structures that characterise most educational systems. This relates to the reproduction of social structure in society through education and is a deeply political activity.

There is an age old saying that knowledge is power. Rouse (1987) also notes that knowledge and power are integrally related and suggests that there are three main ways in which this interaction occurs. Firstly, knowledge can be used to achieve power, secondly knowledge can be applied to deny power to others and thirdly, sometimes knowledge can be used to liberate people from oppression by others. All of these are political acts where people seek to either dominate or empower others.

Therefore, the selection of what is taught, how and when it is taught are also political acts, and as Hargreaves (1994) notes, such decisions have often been used to lend support for certain political agendas, like providing vocational and technical education to working class children as opposed to

the more academic subjects for upper class children. This is concerned with the political economy of education which relates to the way in which knowledge is produced and distributed in society (Papagiannis, Klees and Bickel, 1982).

Education may therefore have ideological underpinnings such as the desire to retain the status quo, or to develop an alternative ideology. In South Africa the indoctrination of Christian National Education (CNE) through fundamental pedagogics serves to remind us of the role that ideology can play in supporting state structures and their underlying agendas (Ashley, 1989). The CNE ideologies were interpreted into forms of control, inferior education and a reduction in the provision of facilities for Black people. This resulted in vast inequalities between the provision of education for Whites and for Blacks in the country. The 'hidden agenda' was clearly underpinned by ideological beliefs held by the ruling government, that Blacks were inferior to Whites and should be dealt with accordingly (Christie, 1985).

Again, whilst it is not the intention of this study to provide a full analysis of the political dimensions of science, nor of education and curriculum, the author acknowledges this as an important determinant in the development of science education.

### **2.3 A closer view of paradigms in education and philosophies of science**

Guba and Lincoln (1989) and Guba (1990) ask three basic questions as a way to characterise different paradigms. These are the ontological, epistemological and methodological questions. The ontological question is, what is the nature of reality? The epistemological question is, what is the relationship between the knower and the known? The methodological question these two authors

ask is, how should the enquirer go about finding out knowledge?

Each of the three paradigms previously outlined from Popkewitz (1984) will be described and then outlined with respect to these three fundamental questions. Major criticisms of each will then be detailed. The purpose of this is to develop a theoretical framework for the subsequent analysis of trends in science education in chapter 3.

The practice of science will also be reviewed and an attempt made to relate some of the different philosophies of science to the paradigms described.

The philosophy of science involves debate that is traced back to Plato in the time of ancient Greece. This has been an ongoing and complex debate involving many different schools of thought. Some authors, like Proctor (1991) and Hassard (1993) provide an overview of how theorists, like Comte, Kant, Bacon, Mill, Spencer, Durkheim and Popper have contributed to the development of positivist science. A critique of positivist approaches is provided from within an interpretive framework, drawing on the hermeneutic tradition (Rouse, 1987), and from a critical perspective, drawing on the work of several critical theorists such as Aronowitz, 1988 and Proctor, 1991.

Whilst there are several philosophies of science, only three will be considered here, namely, logical positivism, wholism and neo-Marxist science. The purpose of the discussion of philosophy of science in this thesis will not be to trace historical origins of particular schools of thought. Rather, an attempt will be made to present the main tenets of three schools of thought, and then to relate these to paradigm theory. A critique of the different philosophies will also be made in an attempt to begin an exploration of the implications for science education.

### **2.3.1 Paradigms in education: An empirical-analytic paradigm**

Within this paradigm, inquiry is concerned with observable and empirical phenomena accompanied by the search for law-like regularities. The world is viewed as an objective reality that can be analysed and reduced to its component parts and it is assumed that it is possible to find rules and generalisations that can be applied to any context in order to predict and control behaviour. Experimentation, through the application of accepted techniques (such as control and experimental groups) is central to the establishment of such laws. Within this paradigm, value is viewed as separate to fact and any inquiry is therefore value-free and objective. There is a strong distinction between theory and practice, where researchers create, discover or invent theories that determine social behaviour. It is through the application or investigation of theories that fact is established. Practice is subordinate to theory and has led to a major split in education between those who develop theories (e.g. in universities) and those who practice education (e.g. teachers) (Carr and Kemmis, 1986).

There are five main values and assumptions (Popkewitz, 1984) that determine the way in which social science is practised within this paradigm. These are as follows:-

- \* Theory is universal and context independent.
- \* Science is objective and independent of goals and values.
- \* A system of variables, if measured independently, can be used to identify causes of behaviour and to predict outcomes.
- \* Knowledge can be formalised and used as the standard against which to test, through the development of independent and dependent variables.



\* The quantification of any data and its analysis reduces ambiguity and contradictions, thereby making data reliable.

The three questions about ontology, epistemology and methodology can be answered within an empirical-analytic paradigm as follows. In this paradigm a realist (Guba and Lincoln, 1989) and an atomistic ontology (Stockman, 1983) are reflected. A realist ontology suggests that there is a reality 'out there' that is driven by predetermined and unchanging laws. An atomistic ontology implies that the world is composed of and can be analysed into increasingly smaller components. This is essentially a reductionist view of reality.

A dualist objectivist epistemology (Guba and Lincoln, 1989) is assumed in which knowledge is independent of any observer and can be exactly understood through appropriate investigation and quantification. Values, interests and assumptions are automatically excluded from such inquiry.

An interventionist methodology is adopted (Guba and Lincoln, 1989). Analysis is conducted through the hypothetico-deductive method. In this approach questions or hypotheses are stated in advance of investigation and are subsequently subjected to investigation through experimental conditions that emphasise control and experimental observations. In this way hypotheses are either falsified or proved. Methods employed to gather data include questionnaires, interview schedules and sampling. Data collected is usually quantitative and is subjected to statistical analysis.

### **2.3.2 Philosophies of science: Logical positivism**

Logical positivism refers to the approach to scientific investigation that employs an inductivist approach to knowledge acquisition. The essential characteristic is that the world cannot be known except through experience of it through the senses. Observation is a fundamental way of finding out about the world. There are several antipositivist theories that have been established as alternatives to logical positivism, including critical rationalism developed by Popper (Stockman, 1983). Popper developed the hypothetico-deductive method of science in which theories are established a priori, and submitted to falsification through experimentation. Whilst Popper did not see himself as a positivist (Longino, 1990) he has been criticised by some theorists in the Vienna Circle for having ‘merely substituted falsibility for verifiability, thus ‘solving’ the problem of induction, but otherwise left everything as it was’ (Stockman, 1983, p 23). From the point of view of critical theorists, a widened notion of positivism has developed that encompasses both inductive and deductive approaches to scientific investigation. This is the common way in which the term positivism is used.

Aronowitz (1988) notes four basic tenets of positivism, namely, (1) qualitative approaches are excluded and mathematical quantitative approaches take precedence, (2) empirical enquiry that excludes speculation is imperative, (3) knowledge is free of value implications and (4) the scientific method is the only way to confirm knowledge. Thus, the positivist position assumes that there are correct methods for doing science and potential researchers are inducted into these methods. A central posit of positivism is that knowledge is acquired through experimentation and empirical evidence gathered through an objective process by the researcher. ‘Valid knowledge can only be established by reference to that which is manifested in experience’ (Carr and Kemmis, 1986, p 61)

and the researcher does not interfere with this process. Knowledge is therefore devoid of value implications. Another central tenet of positivism is that knowledge is developed cumulatively and that the role of scientists is to unlock all of the secrets of nature. This results in the search for law-like regularities that can be used as the basis on which to establish other theories or the basis on which to predict and control events and nature.

It is apparent that there are very strong parallels between positivism and an empirical-analytic paradigm. This is not surprising because Comte, who is attributed to having given sociology its name was also a major contributor to the 'positive' approach to scientific knowledge (Hassard, 1993). Thus both have common roots. Comte was concerned that sociology should explain social phenomena and that this should be done through the testing of theories through observation. This method would develop 'a grand 'positive' scheme for planning the reconstruction of society' (Hassard, 1993, p 16). So, the premises of positivism were at one time generally adopted in most branches of sociology as the dominant paradigm framing theories and research. This trend is clearly seen in the historical dominance of behaviourist psychology, functionalist sociology and objectives driven education. The functions of society are seen as mechanisms driven by the same laws of nature. Grundy (1987), after Habermas, calls this the technical interest in which the fundamental interest of inquiry is the development of sets of rules that can guide action and control the environment.

There have been strong criticisms of positivism in both the natural sciences and the social sciences. Developments in the field of quantum mechanics have shown that the researcher and the phenomenon being investigated are intimately related in a dialectic process. Essentially this has required a shift from a view of reality as a world out there that is based upon absolute truths to a

view of reality dependent upon the observer (Zukav 1979). Thus, it becomes impossible 'to describe events in terms of properties of objects independent of the situation of the observer' (Aronowitz, 1988, p 241). Similar critique has also come from the field of biology and ecology (Capra, 1983). Such challenges have opened the door for a re-examination of the epistemological basis for the practice of science. Thus, Guba and Lincoln (1989) are of the opinion that there is sufficient evidence from physics and mathematics to 'attest to the intrinsic and ineluctable interconnectedness of all phenomena, human or otherwise' (p 66). Because of this they suggest that it is absurd to base the human sciences on the belief that an 'objective dualism is possible' (p 67).

Some authors have proposed other philosophies, such as scientific realism (Stockman, 1980), critical realism (Guba, 1990) and contextual empiricism (Longino, 1990) as alternatives to the positivist tradition. These are all premised upon empiricist assumptions, but Longino notes that her alternative is 'a modest, pared down empiricism' (p 215). Whilst these alternatives do suggest some alternatives to positivism, Guba (1990) notes that they are still rooted in a realist ontology and have strong links to a positivist view.

In the education sphere there has often been strong criticism of the scientism inherent in many models of education, such as the behavioural objectives model (Stenhouse, 1978; Hlebowitsh, 1992). These models are premised upon positivist views of education which hold that learning can be controlled through carefully specified behavioural objectives and positive behavioural reinforcement. This is reminiscent of a scientific approach to experimental design and control.

Similarly, the large scale curriculum development initiatives, commonly referred to as research, development and dissemination initiatives (Havelock, 1971) have also received substantial criticism

as they have not produced the desired changes (Papagiannis, Klees and Bickel; House, 1985, Lapp, 1995a). These initiatives were based upon the assumption that change in education practice could be implemented through centrally managed, rational processes. Thus, Cornbleth (1990) is critical of the way in which the technocratic approach to education has led to a decontextualisation of curriculum and a separation of curriculum design from policy making and implementation. Centres in which decisions are made about education have become separated from centres of action, namely classrooms and schools. This can be attributed to the positivist position that advocates the separation of theory and practice. Similarly, Carr and Kemmis (1986) are also critical of positivism in education because this position does not recognise that education occurs in a social, historical and political context and that social factors play a crucial role in the production of knowledge.

### **2.3.3 Paradigms in education: A symbolic science paradigm**

Carr and Kemmis (1986) note that the challenges to the positivist approaches to education have led to the search for new epistemologies. They suggest that the most popular alternative has been derived from research in the social phenomenology of Alfred Schutz and the sociology of knowledge derived from Berger and Luckman. This is commonly known as the interpretive tradition of social inquiry and serves the practical interest outlined by Grundy (1987) in which the fundamental concern is to generate understanding of the environment through interaction that leads to a consensual interpretation of meaning.

Popkewitz (1984) calls this the symbolic science paradigm. Within this paradigm emphasis is placed upon discourse and the joint construction of meaning. This occurs through a process of mutual negotiation which in turn leads to intersubjective consensus on particular issues. The validity of any

knowledge construct is therefore a negotiated one. The purpose then is to identify and record symbolic interactions and patterns of conduct, that is, rules that govern social interaction and the ways in which those rules are made. Thus, the interpretive mode of inquiry is concerned to find out 'what is' and not 'what it might be' nor 'why it is'.

Subjectivity is accepted within this paradigm because knowledge generated is about the way in which subjects (rather than objects) interact with the world and with each other. The different interpretations of different subjects are given equal status. Thus, patterns of interaction are used as explanatory tools, rather than simple linear cause and effect relationships.

The methods used in generating knowledge claims are characteristically hermeneutic and dialectic. This is an ongoing process of evolving successively more sophisticated accounts of events. It is dialectic as it involves the comparing and contrasting of conflicting constructions, thereby enforcing a reconsideration of previous ideas in a 'back and forth' or 'circular' manner. Thus, Stockman (1983) states that the hermeneutic interpretation is a dialogic activity which mediates individually interpreted experiences through shared systems of cultural meaning.

Another important hermeneutic concept is that of application which aims to link understanding with action, so that individuals are enabled to act 'in order' to cause some event or change. Human action is distinct from human behaviour as actions involve meanings, whilst behaviour alone does not (Carr and Kemmis, 1986). Human judgement is important in the process of developing or deciding on appropriate action. Within the symbolic science paradigm theories are generated through processes of interaction but these are not used to drive action in a technical sense, as is the case in an empirical-analytic paradigm. Rather, theories or ideas are used in association with

practical knowledge and judgement in order to act in an appropriate manner.

From the following quotation from Habermas (Habermas, 1972, cited in Stockman, 1983) a relativist ontology is implicit in a symbolic sciences paradigm. 'It (hermeneutic understanding) is distinguished from the technical cognitive interest in that it aims not at the comprehension of an objectified reality but at the maintenance of the intersubjectivity of mutual understanding, within whose horizon reality can first appear as something'. It is accepted that different actors in societies have different perceptions and understandings of the nature of the world around them and use different symbols to represent that world. Thus, there are several realities that can exist as mental constructs and these are socially and experientially based. Any understanding of reality is constructed out of those different interpretations.

This paradigm adopts a subjectivist epistemology because knowledge claims are generated through the interaction between different subjects, in the particular context in which they find themselves. Knowledge claims are informed by practical experience and previously agreed theories. Thus the known cannot be separated from the knower.

A hermeneutic methodology that involves the dialectic process previously described is implicit in this paradigm. Research is characteristically small in scale and often adopts a case study methodology. Observation research, like participant observation, intersubjective debate and hermeneutic circles are methods often used.

The ontological, epistemological and methodological views outlined here are akin to the alternative or constructivist paradigm that is outlined by Guba and Lincoln (1989) and Guba (1990).

According to these authors a constructivist paradigm is embedded in a relativist ontology, adopts a subjectivist epistemology and a hermeneutic methodology. Guba (1990, p 25) further suggests that there are four basic beliefs of constructivism, namely:-

‘the theory ladenness of facts,  
the underdetermination of theory,  
the value ladenness of facts,  
the interactive nature of the inquirer/inquired-into dyad.’

Their alternative paradigm clearly is embedded in a symbolic sciences paradigm. Driver and Oldham (1986) also note that constructivism has ‘its roots in the long-standing epistemology of the interpretive or *verstehen* tradition’ (p 106).

In a critique of the hermeneutic tradition, Stockman (1983) notes that Habermas does not believe that hermeneutic understanding is sufficient as a method in the social sciences. Firstly, he suggests that the social sciences should also be concerned with identifying and analysing ‘relatively stable and widespread empirical regularities in social action’ (p 154) and this is not possible within the practical interest. His second argument is that hermeneutic understanding ignores the political dimensions inherent in dialogue and acts of communication. The equality of individuals is assumed and this is not the case in society at large. Thus, hermeneutic understanding is not likely, on its own, to unmask ideological positions, underlying assumptions, and constraining factors in society. He suggests that the interpretive model cannot contribute to transformative processes in society. Associated with the latter is a third objection which is critical of the idea that any explanation arrived at must be compatible with the actor’s own account of events. Carr and Kemmis (1986) question how this position can be reconciled with situations where people’s self understanding is compromised by their lack of understanding of social and political forces that are in operation.



Thus, these people may be ‘conditioned by a false consciousness’ (p 96) of how society operates, thereby denying them the chance to see how things really are.

Other criticisms of the interpretive approach have come from positivist oriented critics. They have argued that the interpretive approach is unable to show broad generalisations and that there are no mechanisms or criteria for validating findings (Carr and Kemmis, 1986). However, Guba and Lincoln (1989) and Lincoln (1990), through the development of alternative criteria for evaluating the adequacy of findings and the adequacy of reports, have gone some way to dispelling the latter criticism. They highlight that within a new paradigm there is a need for new terminology and new standards for the assessment of research. Traditional terms and standards cannot be used to do this and so they propose a number of new concepts and terms for judging the quality of educational inquiry. They motivate several criteria for assessing the processes of educational inquiry under the umbrella of ‘trustworthiness’ criteria and ‘authenticity’ criteria which are intended to provide an alternative set of criteria to those traditionally used to assess case study reports.

#### **2.3.4 Philosophies of science: Wholism**

The major challenge to logical positivism in the natural sciences has come from three philosophers of science, namely Hanson, Kuhn and Feyerabend (Longino, 1990), who examined progress in science from a historical perspective. Their historical analyses highlighted that scientific knowledge is not gathered through a process of accumulation, but rather proceeds through periods of ‘revolution’ in which major frameworks and theories are reviewed.

Logical positivism has as one of its fundamental tenets, the notion that observation is conducted

independent of theory and leads to the establishment of correct theories. In contrast, the historically oriented critics showed that existing theories actually influence and frame what is observed. They also showed that the same set of data can be interpreted in totally different ways, depending on the theory used to interpret the findings. Thus, they introduced the concept of theory ladenness, applicable to both observation and meaning. Their insistence 'that elements of a theory, including its supporting data, can only be understood in the context of the whole' has given rise to the designation "wholism" for this family of views (Longino, 1990, p 27).

Kuhn and Feyerabend also developed the concept of incommensurability (Hassard, 1993), which suggests that two competing accounts of a set of observations or data can never be compared with each other in any way that will determine which is true or false. This has led to a strong critique that their position places scientific endeavours within the realm of complete subjectivism and relativism.

Methodologically, Feyerabend (1975, cited in Millar and Driver, 1987, p 39) argues that 'the idea of a method that contains firm, unchanging, and absolutely binding principles for conducting the business of science meets considerable difficulty when confronted with the results of historical research'. Similarly, Newton-Smith (1981) suggests that there are no rules which can be used at the point when a scientist needs to make a judgement or decision. Thus, Millar and Driver (1987, p 38) conclude that 'there is no algorithm for gaining or validating scientific knowledge'. Their argument is directed against the positivist belief in **the** 'method of science'.

Rouse (1987) extended this by arguing that science is firmly embedded in a practical hermeneutic tradition. He uses this position to analyse Kuhn's (1970) book The structure of scientific revolutions and provides an alternative interpretation of Kuhn's work. Rouse (1987, p 39) argued

that ‘scientists do not normally test theories; they use them’. In this way theories are utilised in the practical sense of a symbolic sciences paradigm where knowledge and theories are used to make prudent judgements and to direct, but not control, action. Theories are taken as extendible models and not fixed truths. He argued for a concept of science that embodies ‘theory as practice and research as action’.

He also argued that theory-dominant views of science have been over exaggerated because scientists often do not use theories to determine what research is undertaken, but also adopt an ‘opportunistic conception of research’ (Rouse, p 88). The motive for conducting research is not the identification of a problem, but the identification of an opportunity. In this sense research is driven by a complexity of factors that are available in order for the research to be conducted, like skills, practices, interest, equipment, as well as theoretical models. The results of research are then used to dialectically inform theory and further practice. Thus his argument for ‘theory as practice and research as action’ (Rouse, p 88). He also noted that the results of the research are usually not applied as immutable laws and generalisations, but rather as new practices in new local contexts.

Research results are subjected to an appraisal and critique by the broader community of researchers and in this way a body of knowledge becomes socially constructed and accepted. This social character in science is recognised by Habermas (in Longino, 1990) who claims that ‘the intersubjectivity of a community of investigators is the ground of clarification of metatheoretical problems of the natural sciences’ (p 198). This also means that a random collection of subjective personal ideas and preferences is minimised, laying to rest the concerns about extreme relativism.

Clearly, this approach to the development and understanding of the practice of natural science is

closely aligned to a symbolic sciences paradigm. Key elements include the hermeneutic tradition in the practice of science, the way in which theories are used to guide practice, the acceptance of the value ladenness of theories and of facts, as well as the acceptance that science is not a fixed body of knowledge.

However, even Rouse (1987) acknowledged that his analysis takes Kuhn's views 'further in the direction of an account of science as practice than he himself would be happy with' (p 27). Thus, one needs to question the extent to which this view is debated by or even understood by practising scientists. Certainly, it seems that the majority of science is not concerned with this interpretation of the relationship between theory and practice. Indeed, it certainly seems that most scientists are only concerned with the practice of science as what Gribbin (1984) calls science technicians, practising 'quantum cookery' (p 152). He highlights how quantum mechanics has been used to develop laser, micro chip and superconductor technology, and yet many of the scientists employing these techniques do so without appreciating the underpinning philosophical implications of quantum mechanics. Nor are they interested in the development or redefinition of theories.

### **2.3.5 Paradigms in education: A critical sciences paradigm.**

A second challenge to the rationalism of positivism came from a group of philosophers and social scientists generally known as the Frankfurt School (Carr and Kemmis, 1986). This view of theory is commonly known as critical theory, although the term can be interpreted in different ways. Essentially, critical theory is concerned with trying to establish the relationship between value, interest and action in order to change the world and not to describe it (Popkewitz, 1984). Habermas has extended this to a critical social science that bridges philosophy and science (Carr

and Kemmis, 1986).

The main interest to be served within this paradigm is an emancipatory one (Grundy, 1987) in which individuals are empowered to 'engage in autonomous action arising out of authentic, critical insights into the social construction of human society' (p 19). Thus, the purpose is to unmask myths, assumptions and constraints that restrict human action and to understand the dynamics involved in social change. Critical theories are about the liberation of individuals from oppressive forces in society. Causation is viewed in historical terms, that is, reality is a result of the historical and political actions of individuals and because of structural edifices that have been created. The main features of this paradigm are rooted in experiences of the world as a concrete social phenomena (Carr and Kemmis, 1986).

This view of the world is strongly dialectic in several senses. Firstly, society is seen as a human product, but man is seen as a social product, with society mediating between these two positions as an objective reality. Furthermore, every change is a change in itself, but in turn changes the world and therefore the form of objectivity. Additionally, there is a dialectic relationship between theory and practice. Theory informs practice and practice informs theory in mutually dependent ways, known as praxis (Popkewitz, 1984).

Knowledge of the objective world is generated through reflection and introspection that aims to expose the forces of oppression. Knowledge is geared to action in order to undermine the dominant mechanisms that create a false consciousness. The driving force behind action is to free the individual and society from dominant ideologies and interests.

Guba (1990) describes the critical science paradigm with respect to the ontological, epistemological and methodological questions outlined earlier. He suggests that a critical sciences paradigm adopts a critical realist ontology (Guba, 1990). This position is reflected in the view that ‘the subjective meanings that characterise social life are themselves conditioned by an objective context’ (Carr and Kemmis, 1986, p 135). Objective reality arises out of ideologically and politically driven situations and structures and these in turn empower or dis-empower our lives.

A subjectivist epistemology is assumed within this paradigm (Guba, 1990) because it is accepted that values are intimately coupled with action and with inquiry. Also, it is a premise that humans create personal and subjective meanings out of their reality. It is these subjective accounts which need to be exposed and replaced with the ‘truth’ in order to overcome what those operating in a critical sciences paradigm call ‘false consciousness’.

Carr and Kemmis (1986, p 146) contest that the epistemological position adopted is constructivist because knowledge develops ‘by a process of active construction and reconstruction of theory and practice by those involved; that it involves a theory of symmetrical communication; and that it involves a democratic theory of political action based on free commitment to social action and consensus about what needs to be and should be done.’ At this point the critical sciences perspective sounds remarkably similar to that advocated by Guba and Lincoln (1989) in which they elaborate how evaluation conducted within a constructivist paradigm can lead to the empowerment of individuals.

A critical sciences view embodies a dialogic, transformative methodology (Guba, 1990). These dialogic, transformative methods rest on Habermas’s theory of communicative competence and in

particular on the notion of rational communication (Carr and Kemmis, 1986). This position suggests that it is possible to create conditions in which all participants are free and equally able to enter into discourse. It also assumes that decision making which arises out of the communicative action can be driven 'by the rationality of the arguments for different courses of action' (p 146). Other methods often used include historiography and action research.

Carr and Kemmis (1986) note that the theory of communicative competence is not a finished product. However, even given this constraint there are several criticisms of the critical social science perspective. Not least of all is this lack of detailed clarity on the epistemological and methodological procedures. Bernstein, 1979 (cited in Carr and Kemmis, 1986, p 140) also notes that 'Habermas seems to be smuggling in his own normative bias under the guise of objective analysis of reason and self-reflection'. This is a criticism of the critical realist ontology, that it is believed that the critical researcher is able to use his own normative perspectives and prejudices to arbitrate between true and false constructions.

Similarly, Guba (1990) is also critical of the realist ontology assumed in the critical social paradigm. He says that the move toward a subjectivist epistemology represents a step forward, but that with a realist ontology most of the value of this position is lost.

These criticisms of a realist ontology point towards a major contradiction in the critical sciences paradigm. Carr and Kemmis (1986, p 136) suggest that Habermas' attempt to elaborate a critical social science is driven by his desire 'to reconcile his recognition of the importance of both 'interpretive and causal explanations'. Interpretative accounts are necessarily subjective, but an objective position is adopted with respect to causal relations because these lie outside of the

individual. However, there is a sharp contradiction in this; that individual knowledge is personally constructed and therefore subjective, but that social products which are also socially constructed are objective (real). It can be argued that in the same way that personal knowledge is subjectively constructed, so is knowledge of social situations. That different persons interpret social, political and historical events differently implies that these too are subjective constructs.

In contrast to this position, the constructivist paradigm elaborated by Guba and Lincoln (1989) and Guba (1990) adopt a relativist position on both ontology and epistemology. However, in contrast to the position adopted in a symbolic sciences paradigm, they include elements of a critical perspective. The role that they elaborate for the researcher or evaluator is clearly a political one - that of a broker of information. The researcher is also an active agent of change with a moral responsibility to educate all stakeholders, to develop conceptual parity and to reveal power relations, in order to ensure that all stakeholders have an equal capacity to act. These are all political roles. They are also clear on the values that should be adopted to direct inquiry, including respect for alternative constructions, stakeholder participation and collaboration, deliberation, meaning making and consensus generation. These suggest an assimilation of elements of the critical sciences paradigm, that lead to the 'empowerment and enfranchising of less powerful groups' (p 65), within an interpretive or symbolic science paradigm already described for their work.

Thus, the constructivist paradigm outlined by Guba and Lincoln (1989) is more synonymous with the radical humanist paradigm outlined by Burrell and Morgan (1979, cited in Hassard, 1993) as it is embedded in a relativist ontology and accepts that knowledge is socially constructed, but adopts a radical perspective which attempts to highlight 'the alienating modes of thought which characterise modern industrial society' (Hassard, 1993, p 89). That there are different conceptions



of paradigms suggests that paradigms themselves are human constructs which aid thinking and analysis, but which are not discrete, 'real' entities.

### **2.3.6 Philosophies of science: Marxism and neo-Marxism**

Longino (1990) notes how science and ideology are intimately linked. This is also clear from the earlier discussions presented about history and politics as determinants of the practice of science. Longino (1990) presents perspectives from a range of neo-Marxist scientists who all address the relationship between science, politics and ideology and who seek to conduct science from within their particular political framework. The purpose of doing science is to 'reveal different relationships' (p 197) and to provide alternative explanations for phenomena from within one's explicit value position. The views outlined include those from radical scientists, feminist scientists, Foucault and Habermas. All of these theorists draw on critical theory for constructing their arguments.

Longino (1990) notes that there are three basic ways in which neo-Marxists characterise scientific knowledge. Firstly, there is the recognition that the application of science for political ends (like warfare, biological engineering, automation) is a direct result of 'bourgeois science' (p 194) and not the misguided application of neutral science. Secondly, there is a rejection of reductionism because this 'reflects the bourgeois interest in centralized control' (p 195). The third characteristic of neo-Marxist science is that it seeks to be emancipatory by adopting methodologies that seek to expose the contradictions in society. This includes the rejection of the object-subject duality in an attempt to develop a dialectic view of nature. These premises clearly relate to those outlined in a critical sciences paradigm. However, Longino notes that the theoretical bases of how and why a dialectic

and emancipatory science should be practised, have not been well spelled out by proponents of these approaches. Further work is needed in this regard.

Longino (1990) also presents science from the perspective of different feminists, including herself and shows how framing theories and values about gender can influence the way research is conducted, how results are collected and how the research is interpreted. She goes further to note that even within feminist writings there are different perspectives and approaches adopted by different writers. Some writers call for an interactionist view in which space is made to express particularly feminine traits, like co-operation and interaction, in the practice of science. However, Longino (1990) notes that this cognitive approach to feminism has its limitations because women are socialised into particular roles and may only exhibit certain predispositions (traits) for those reasons. Thus, she adopts a more critical approach to feminist science.

Longino (1990) is also critical of Habermas, stating that ‘in trying to clear a space for autonomous social and critical theory, he has ceded nature to the positivists’ (p 202). Similarly, she is concerned that Foucault’s ideas do little to reduce the effects of power, but rather lead to the realignment of power in another structure.

Whilst all of these neo-Marxists theorists agree that science is politically motivated, they disagree on the role of the different human interests and on the epistemological and methodological bases of scientific enquiry. There is no one position for the practice of science within a neo-Marxist tradition. Thus, Aronowitz (1988, p x) states that his critique of science is not intended to ‘outline a new science’ but to place science under scrutiny in order to encourage greater discussion about theory and practice. Unless this happens, science’s ‘power will remain beyond challenge’. The

limited number of alternative examples of practice cited by these authors, suggests that there has been little impact of critical theory on the theories and practices of science. Much of science appears to proceed by 'business as usual' and one is left questioning the extent to which authors like Aronowitz (1988) have achieved their objective of encouraging concerted debate within the broader scientific community.

### **2.3.7 Concluding discussion**

In this chapter an attempt has been made to relate modes of inquiry in particular paradigms in the social sciences (including education) to philosophies of science, in order to show if they are compatible. Parallels between these have been explored and made explicit with respect to ontology, epistemology and methodology. It is shown that an empirical analytic paradigm is derived from the philosophy of logical positivism. A symbolic sciences paradigm is linked to the philosophy of wholism. A critical sciences paradigm bears similarities to a neo-marxist philosophy of science, although modes of inquiry in the latter have not been adequately developed.

Hassard (1993) questions the incommensurability principle outlined by Kuhn which suggests that it is not possible to compare competing paradigms because each utilises different concepts, languages and procedures. However, he notes that even Kuhn later rescinded on his rigidity about this principle agreeing that different languages could be translated, but only up to a point, whereafter meaning is lost. Thus, Hassard (1993) suggests that paradigms are not hermetically sealed entities that cannot be entered by others operating out of another paradigm, but rather that paradigms are porous. He goes further to provide a theory for paradigm mediation based on Wittgenstein's language-game of every day life, which highlights the socially constructed nature of language.

Hassard (1993) also provides a methodology for multi-paradigmatic research.

Similarly, Bernstein (1991, cited in Solomon 1994, p 6) who draws on post-modernist thinking, agrees that 'Incommensurable languages can be compared and evaluated in multiple ways. Practically, such comparison and evaluation requires cultivation of hermeneutical sensitivity and imagination.' Thus, it is necessary to apply multiple forms of analysis and to recognise patterns of language in use.

If paradigms can be mediated, this opens the path for the generation of new methodologies and epistemologies in sociology, science and in education. In Hassard's case this translates into 'a research methodology which employs a plurality of sociological paradigms and an epistemology which forms the basis for a postmodern approach' (Hassard, 1993, p 1). Also, it has been noted that there are different ways of conceiving and categorizing paradigms, which means that they are not mutually exclusive and sealed 'real' entities. This creates space for the reconceptualisation of approaches to education, including science education and curriculum development.

The debate around paradigms in sociology and in education is alive and well. Whilst much of this has been geared to refuting positivist approaches within both fields, a rich body of knowledge exists about the ontological, epistemological and methodological assumptions of the different paradigms. This is in contrast to philosophies of science, where examples of the practice of science from within different paradigms is limited. Hassard (1993, p 56) notes that whilst Kuhn primarily spoke to natural scientists, 'his ideas were accepted readily by social scientists' and he suggests that a 'Kuhnian revolution swept across Western sociology in the late 1960s and early 1970s' (p 49). This revolution does not seem to have touched the natural sciences in the same way as it appears that

discourse about alternative approaches is limited. Aronowitz (1988, p x) notes that philosophy and the history of science have tended to promote rather than challenge the sciences and in this regard 'philosophy has become the servant of the sciences'.

Rouse (1987) argued for a hermeneutic or interpretive interpretation of Kuhn, but acknowledges that this goes further than even Kuhn intended. Also examples of his suggestion of 'theory as practice and research as action' are limited and may be a result of historical interpretation (e.g. his argument about the discovery of the DNA code by Crick and Watson) rather than a planned and deliberate approach to research.

Similarly, the challenge to the traditional view of science provided by quantum mechanics which fundamentally questions the object-subject duality, has been generally ignored by most scientists who continue to practice science in positivist ways. As Aronowitz (1988) notes this challenge has been resolved in physics by the realist principle of indeterminacy which corrects for this phenomena. However, he also records the dissent of some theoretical and philosophically minded physicists who question whether this is a sufficient explanation.

Further evidence of the lack of substantial and sustained debate comes from the critical theory perspective of science, where it was shown that there is a lack of cohesion and insufficient examples of theoretical discourse. Thus, alternatives to the practice of science do not sufficiently challenge the positivist ontology, epistemology and methodologies which drive the practice of the natural science. We seem to be locked into a traditional view of science. This is a crucial consideration for science education because this position is likely to be reflected in its purposes and practices.

Given the previous discussion of paradigms in education and philosophies of science, it can also be suggested that science education is likely to also be without clearly articulated alternative paradigms. Yerrick and Nugent (1996) suggest that science educators need to 'adopt a different lens through which to view the problems of teaching and learning science' and to 'develop new ways of talking about science learning, teaching and scientific literacy'. So, what are the paradigmatic frameworks driving science education? Where alternative paradigms for science education exist, there are likely to be tensions between those paradigms and the positivist philosophy still dominant in the sciences. So, what alternatives are possible?

Hodson (1988, p 26) noted that there are 'two important questions for science curriculum designers (1) What is the status of scientific theory, and (2) What is the role of theory in science?' He added that consideration of the first question raises the 'realism - instrumentalism controversy' and suggested that teachers should 'teach within the prevailing paradigm' (p25) but make it clear to pupils that 'theories are, temporarily at least, regarded as true descriptions of the world'. This is the paradox for science educators - how to adopt a constructivist teaching style within the traditional paradigm of science. The typical approach advocated is to establish what pupils think and 'lead' them to the accepted scientific explanation. Thus, constructivist approaches to science education have been criticised on the basis that they are founded on empiricist views on the natural sciences (Matthews, 1992; Osborne, 1993, cited in Driver, *et al* , 1994). For instance, Matthews (1992) says typical constructivist thinking is rooted in the Aristotelian epistemology 'which formulates the problem of knowledge in terms of a subject looking at an object and asking how well what is seen reflects the nature or essence of the object' (p 302). Thus, constructivists talk of individuals making sense of their sensory inputs and being assisted to make sense of the world around them. This is essentially empiricist as it relies on a subject-object duality and suggests that

there is a 'truth' children need to be led to.

Similarly, Solomon (1994) suggests that constructivism is a redescription of an approach that already existed, but that it was rephrased in new language. It was this new language that led to the generation of new theories and areas of interest. For instance, the old vocabulary focused on pupils 'making common mistakes' whilst the new language focused on childrens' existing ideas, preconceptions or alternative conceptions.

Because of these tensions, it is suggested that paradigms for science education need to be more coherently developed and articulated. Before this can be done, it is necessary to examine which paradigms are driving the current conceptions. This is the topic of the next chapter in which the various paradigms are used as conceptual tools for purposes of analysis and critique.

## **CHAPTER THREE**

### **TRENDS IN SCIENCE EDUCATION**

#### **3.1 Introduction**

The purpose of this section is to review some of the literature on emphases, perspectives, orientations, priorities and approaches which are relevant to all levels of science education. Various key aspects and issues are briefly described and then analysed with reference to the paradigms described in the previous chapter. This is done in order to locate the main trends in science education within particular paradigms. This provides an understanding of the dominant views of the nature of and approaches to science education and opens the path for the exploration of alternative paradigms and modes of inquiry in science education and curriculum development.

Thereafter, a framework for curriculum analysis is developed based on a set of key curriculum determinants described within each paradigm. This tool is developed for use in the analysis of emphases in primary science education in the next chapter.

#### **3.2 Paradigms as a framework for theoretical analysis in education**

Paradigms have been used by several authors as the basis for the analysis and categorisation of different approaches to education.



Rogan and Luckowski (1990), in their analysis of major texts used in curriculum courses, showed that only one text author, namely Schubert (1986), 'stands alone in his elevation of practical inquiry and critical praxis to the status of a paradigm' (p 20). They also note that paradigms in curriculum should develop a theoretical explanation of curriculum and suggest that, given this fundamental criterion, curriculum can be considered to be 'without a paradigm, rather than subject to competing paradigms' (p 22). This again suggests the need for the clearer articulation of paradigms in curriculum and related fields, like science education.

In another analysis involving the use of paradigms, Farnham-Diggory (1994) identifies three core instructional paradigms. These are derived from cognitive science and stipulate the instructional paradigms within which knowledge can be acquired, namely a behavioural paradigm, a development paradigm and an apprenticeship paradigm. Within this he identifies five types of knowledge, which are briefly described thus: declarative knowledge which is knowledge that can be stated; procedural knowledge which is knowledge that can be shown; conceptual knowledge which is knowledge that identifies categories (lists of attributes) and schema (map-like spatial and temporal attributes); analogical knowledge which is knowledge that relates to images of the world; and logical knowledge which is knowledge of causal relationships.

He uses these paradigms and types of knowledge to review the emphases in current literature on instruction. He examined 43 articles and notes that 39 of the articles do not specify an instructional paradigm and that 38 studies emphasise declarative knowledge and 26 emphasise procedural

knowledge. There is very little emphasis on other forms of knowledge. He concludes that this sort of analysis 'identifies the lines of research that the program is truly linked to; and that reveals the degree to which educational science as a whole is (or is not) advancing' (p 474).

In the South African context, Levy (1989) examined the epistemological assumptions implicit in a set of curriculum policy proposal for senior science, produced by the South African Association for Teachers of Physical Science. She notes that the policy proposals suggest a shift beyond the 'empiricist scientific paradigm' (p 44). However, she is dissatisfied with the proposals because they fail 'to recognise and criticise the epistemological and social dimensions of the problems of science education, both of which are vital in the construction of a framework within which to guide the practice of school science' (p 43). Thus, she is concerned that it is not sufficient to only change the paradigm espoused in policy documents. New policy proposals must be considered in the light of the broader paradigm in which society is located.

Similarly, Bhika, Keogh, Patal and Schreuder (1994) use the three paradigms outlined by Popkewitz (1984) to critique three papers presented at a conference of the South African Association for Research in Mathematics and Science Education. They use an analogy of filters which filter out different wavelengths of light and suggest that in the same way one's 'paradigmatic framework acts as a filter to filter out contrary perspectives and highlight perspectives that are in agreement with one's own framework' (p 2). The work of different authors can be looked at through different filters to determine which filter s/he is using, that is, an empirical-analytic filter, a hermeneutic filter or a critical filter. They suggest that the 'paradigm which most closely fits with

the mode of rationality of the author is one which will be the most illuminating' (p 2). Using this technique they highlight underpinning paradigmatic assumptions implicit in three different papers.

So, paradigms can be used to examine particular emphases and traditions within education, in other words for analytic purposes. This can help to identify particular biases of materials, of researchers and of teachers and to expose the dominant emphases within a particular field, like science education. The analysis of dominant trends and approaches, using paradigms, can also contribute to the development of a field of inquiry. For instance, an understanding of the current status of science education and of trends and emphases is an important precursor for development.

In this chapter some of the major trends in science education are analysed in terms of the paradigms outlined by Popkewitz (1984). This is **not** done in order to castigate one approach over the other, or to define an approach to science education. It is done in order to understand the trends in science education and to develop a framework for curriculum analysis that could contribute to curriculum development in this field.

### **3.3 Curriculum emphases in science education**

Roberts (1982) analysed the major curriculum trends in science education policy, in a selection of instructional materials and in classroom practice in the U S A. As a result of his research he suggests that there are seven dominant curriculum emphases in science education, each one advocating a particular view of science and a particular emphasis for science education. He defines a curriculum emphasis as 'a coherent set of messages about science' (p 245) that includes both

what is stated and what is not stated. These emphases can be interpreted as orientations as they elaborate a purpose for science education and ask the fundamental question - 'why am I learning this?' (p 245). A brief description of each emphasis is provided below, presented in the author's order of preference. Thereafter, each of the emphases is analysed using paradigm theory.

**The correct explanations emphasis:** This emphasis stresses science as a set of facts that are produced by an elite group of persons called scientists. It is concerned with students mastering the set of ideas about which there is consensus in the scientific community. It is about 'the authority of a group of experts to determine the correctness of ideas' (p 248).

**The scientific skill development emphasis:** The process skills of science, such as observation, hypothesising and fair testing are major emphases within this orientation. This suggests that the skills used in doing science are important competencies to be learned and applied. The underlying message is that 'skilful use of means (scientific process) will automatically yield a correct end (product)' (p 247).

**The solid foundation emphasis:** Emphasis is placed on learning science in a systematic and logically ordered way in order that subsequent learning can be built on the earlier building blocks. Primary education is seen as a precursor for secondary education as it provides the necessary framework and concepts for further learning. Roberts (1982) notes that this emphasis is silent about the overall purpose to which this logical approach is geared.

**The structure of science emphasis:** ‘The substance of this emphasis is a set of messages about how science functions intellectually in its own growth and development’ (Roberts, 1982, p 247).

The main concern is with the nature of the relationship between theories and the evidence that establishes laws. It is concerned with the way in which science grows and develops and legitimates theories. Kuhn’s challenges, which have already been elaborated, were based upon concerns about the structure of the discipline - the practice of ‘normal’ science and the ways in which changes in that practice occur. The structure of the discipline then is concerned with ‘the context of the logic, general methodology and peculiar character of the scientific enterprise’ (Richards, 1983, p 13).

**The everyday coping emphasis:** The main concern within this emphasis is the application of science to everyday events and situations. Students are encouraged to learn how to apply scientific principles and generalisations (like conductivity of metals) to everyday contexts (like, copper bottomed pots distribute heat more evenly than pots made of other metals, because copper is a better conductor of heat than other metals).

These first five emphases are concerned respectively with views of science as (1) a body of facts derived inductively or deductively from the objective world, (2) with the skills scientists use to do science, (3) with the acquisition of facts in an orderly and logical fashion, (4) with the methods used by scientists and ways in which generalisations are made and (5) the ways in which science can serve society - a technical interest. All five of these emphases carry with them some of the characteristics of science within an empirical analytic paradigms and cumulatively represent the practice of science within that paradigm. However, each has been reduced even further and its emphasis is not related to the whole of scientific enquiry. This is testament to a reductionist

approach to knowledge where science is reduced to even smaller, supposedly independent bits. Clearly science education which adopts any of these emphases is embedded in an empirical-analytic paradigm and a traditional view of knowledge.

**The self as explainer emphasis:** Science within this emphasis explores the ways in which ideas were developed within a particular social and historical context. Science becomes one way of explaining natural phenomena and events. A message is conveyed to the student that s/he is also an explainer of events within his/her own context. Individual constructions are tolerated on the basis that these make sense, given the individual's context, purposes and concerns.

This emphasis is concerned with trying to find ways to understand and explain situations in a social context. This is reminiscent of the key focus within a symbolic sciences paradigm where consensus and meaning making are crucial. Within that paradigm personal constructions are a given and the task is to develop ways in which to act prudently on the basis of practical knowledge. The self as explainer, however, places emphasis on the explanation and does not deal with how this relates to action. In this sense it falls short of being located within a symbolic sciences paradigm.

**The science, technology and decisions emphasis:** This emphasis 'concentrates on the limits of science in coping with practical affairs' (Roberts, 1982, p 24). Within this emphasis it is noted that decisions involving science and technology are necessarily political decisions because they inevitably involve value judgements. Roberts cites the case of the decision of where to place an oil pipeline, stating that whilst scientific knowledge and technical know-how may have a role to play in this, they are of limited value when considering other aspects like human, social, and environmental

conditions. He further distinguishes between science and technology using the work of Schwab (1974). Science is distinguished from technology because it (science) is embedded in the realm of knowledge and theory (the theoretic), whilst technology is a practical issue 'in the Aristotelian sense of wanting a defensible action' (p 247).

This position clearly places the emphasis within a symbolic sciences paradigm, in which prudent action is the ultimate purpose of gathering knowledge and understanding. Also, the subjectivity of knowledge is accepted through an acceptance of the value ladenness of decisions.

Roberts (1982) does not describe a curriculum emphasis that approximates to a critical sciences paradigm. Possibly, in 1982 this was not perceived to be a purpose for science education.

### **3.4 Research perspectives in science education**

Eylon and Linn (1988) in a review of the literature describe four perspectives that have dominated research in science education. All of these research interests are derived from research into cognition and how students learn in the sciences. Each perspective highlights a different aspect of the learner and explores the ways in which knowledge and reasoning processes develop. The four research perspectives are as follows:- (1) a concept-learning perspective, (2) a developmental perspective, (3) a differential perspective and (4) a problem solving perspective. These perspectives provide a useful tool for analysing research interests.

All of the approaches accept the traditional boundaries of knowledge as disciplines. Also the commonly accepted methods or procedures of science are not questioned. Science is not viewed in the sense of practice as outlined by Rouse (1987) in the section on wholism in science (p 37). This implies an unquestioning acceptance of the traditional approach to scientific investigation.

However, all perspectives do represent a move away from a traditional view of education because it is accepted that the learner is central to the educational process. However, it will be shown that some elements of an empirical-analytic paradigm are still evident in most of the perspectives presented by Eylon and Linn (1988), and particularly in the developmental and differential perspectives.

A brief overview of each perspective will be given, including some of the main research findings. Thereafter an attempt will be made to relate these categories to paradigm theory.

**The concept-learning perspective:** This perspective describes a student guided by domain-specific ideas and conceptions and focuses on ‘the content and structure of the knowledge that students acquire’ (Eylon and Linn, 1988, p 252).

Research has tended to focus on exploring childrens’ ideas of scientific concepts in specific topics. This is based on the belief that children create meaning out of their own personal and social situation and develop their own theories about the world. Childrens’ existing ideas are sometimes called naive conceptions, intuitive conceptions, alternative conceptions or misconceptions. A vast



body of research exists that has catalogued the conceptions that children of different ages hold about different phenomena.

Research has shown that conceptions are often very resistant and persist even after conflicting situations have been made available to the learner. Learners often ignore contradictions and may even have several conceptions for the same phenomenon. This suggests a lack of commitment to one view when there are competing or related concepts. Some research has been done on exploring the origins of such concepts and ‘suggests that there are some well-defined mechanisms that lead to their creation’ (Eylon and Linn, 1988, p 257). It is suggested that some of these origins relate to naive observations of phenomena, to the colloquial use of language and to children’s epistemological commitments, including a commitment to a mechanistic world, a lack of commitment to consistency and a belief in the immutability of ‘facts’.

Some research has focused on developing instructional strategies that try to alter the original conceptions. Strategies that seem to have merit in this regard include:- (1) building on naive concepts, (2) providing opportunities for children to challenge existing ideas so that they can see the contradictions and adopt a revised view, (3) providing opportunities for children to link concepts and to develop a network of ideas, (4) elaborating the differences between related concepts, and (5) an in depth coverage of topics as opposed to a breadth of topics, so that children can build a network of concepts about that topic.

**The developmental perspective:** This perspective emphasises the information-processing and intellectual constraints on the learner and ‘includes studies of when in the life span students attain specific concepts’ (Eylon and Linn, 1988, p 252).

This perspective is derived largely from the work of Piaget, in which it is postulated that the ability to engage in abstract thought develops in an age related manner. Neo-Piagetian researchers suggest that it is the ability to process an increasing number of elements and variables at the same time that develops. Results show that there is a direct relationship between age and the number of variables that can be manipulated. This is attributed to an increase in working memory capacity. It has also been shown that abstract reasoning is enhanced when the demands made on the working memory are kept to a minimum. Thus it is the lack of sufficient processing capacity that restricts thinking, rather than a lack of abstract reasoning skills. Other studies in the developmental perspective have explored the ways in which knowledge of science subject matter influences reasoning on Piagetian tasks.

There has been some attempt to relate the developmental perspective to classroom instruction, but Eylon and Linn (1988) state that these attempts have largely been unsuccessful. The attempts have focused on the differences between concrete and formal reasoning and on broad aspects of performance, rather than on identifying specific conditions for conceptual change. Also, research does not emphasise differences in individuals abilities and assumes a fixed approach for all children of a certain age. As a general teaching strategy researchers in this field would suggest the use of Piaget’s notion of reflective abstraction, that is reflection on ideas.

**The differential perspective:** This perspective posits a learner who is governed by general and specific abilities and ‘examines individual differences in abilities and aptitudes’ (Eylon and Linn, 1988, p 252).

Research done within this perspective has sought to explain why some children are better able to do science. The studies have tended to be large scale and have used achievement tests that focus on factual knowledge rather than on individual approaches to scientific problem solving. Researchers have also tended to identify psychosocial variables, like interest in science, confidence and autonomy as well as social variables, like gender, social class and race, and have investigated their effects on science achievement.

Two levels of scientific proficiency are defined, namely crystallised ability which is concerned with the recall of factual knowledge or algorithms and fluid ability which is concerned with abstract reasoning skills, like planning solutions or integrating information. Findings show that domain specific science knowledge is needed in order for students to think abstractly. Thus, it becomes difficult to assess the level of abstract thinking skills when children do not have the requisite content knowledge.

Teaching strategies that are advocated on the basis of research findings include (1) the use of in depth treatment of topics, (2) the provision of explicit instructions as to how to solve problems, in the case of medium and low ability achievers and (3) the use of more than one approach to the same concept.

**The problem-solving perspective:** This perspective depicts a learner using domain-specific and more general procedural skills and cognitive monitoring processes. Studies within this perspective focus on ‘the processes or procedures students employ to answer scientific questions’ (Eylon and Linn, 1988, p 253).

Researchers operating within this perspective have tended to use qualitative approaches in their investigations and so have concentrated on smaller numbers of cases. A particular technique is that where researchers ask individuals to explain in detail how they solve a problem as they are doing it. Thus, the focus is on the content knowledge and the techniques that are used in problem solving.

Findings indicate that content knowledge is important for problem solving and that a systematic and hierarchical organisation, or mental model, of this content further facilitates problem solving. This mental model is most effective when knowledge is organised around central concepts, principles and procedures.

Problem solving researchers have also explored the procedural skills utilised in problem solving, but as Eylon and Linn (1988) note the number of studies which explore procedural difficulties is limited. This is in contrast to the number of studies that have documented students’ conceptions and mental models. Some of the problems noted with respect to procedural skills include a tendency to over-generalisation and the confusion of related terms. They also note that good problem solvers have good planning skills and tend to mentally test their solutions, reflect on and refine them. Research suggests that much of this is learned through experience or is tacit knowledge that even experts find hard to explain. An additional procedural skill that is highlighted

as being particularly effective in problem solving is that of cognitive monitoring or meta-cognition; that is the ability to reflect on and understand one's own cognitive processes. As is the case in the concept-learning perspective, epistemology is also shown to strongly influence the reasoner's approach.

Strategies that could be used in teaching have generally not been explored by researchers working within this perspective. However, Eylon and Linn (1988) suggest some strategies on the basis of research work. These include, (1) providing students with a model for the organisation of knowledge, (2) providing operational models and examples for problem solving, and (3) by 'scaffolding' which allows the students to scaffold or build on their abilities without overtaxing them.

Eylon and Linn (1988, p 288) suggest that the research from the four different perspectives be 'used to mutually support one another'. Thus, they note that there are four commonalities that should be emphasised in science teaching, namely (a) content and representation of knowledge, (b) organisation of knowledge, (c) learner's epistemology and (d) reasoner's general ability, developmental level and information processing ability.

In all of the perspectives the learner and his/her abilities are the focus of research and in many cases researchers are concerned to find ways to promote meaningful learning that acknowledges these abilities. All are cognitive studies that employ empirical methods. Thus, all four perspectives could be classified into Leriche's (1990) category of conceptual-empiricism which he states is premised upon symbolic interactionist (symbolic sciences) assumptions, which include the notion that

knowledge is socially constructed. However, this is true to varying degrees within each of the perspectives.

Within the concept-learning approach the focus is on identifying childrens' existing ideas so that they can be encouraged to construct more scientifically acceptable ideas. Also, researchers are concerned to identify the factors within society that may enhance the formulation of alternative constructions and to develop teaching strategies to promote learning. The emphasis on understanding suggests that this perspective is embedded in a symbolic sciences paradigm. There are also elements of a symbolic sciences paradigm within the developmental perspective, which explores the way in which children engage with abstract thought at different ages. However, in this perspective the emphasis is on how children think and little attention is given to enhancing understanding. Thus, alternative teaching methods have not been well explored. This research perspective thus appears to be more technical.

In the differential perspective there appears to be little emphasis on how knowledge is created by children. Rather the focus is on determining which factors and variables enhance scientific ability in the traditional sense. Thus, there is little consideration of the social construction of knowledge and so this perspective is also more technical.

Within the problem solving perspective attempts are made to identify factors that enhance science performance. Learning through cognitive monitoring is advocated. This meta-cognitive approach can be used to identify why certain concepts are held (including alternative concepts), in addition to reflecting on how best to solve a scientific problem. There is a strong concern for encouraging

learners to understand how they think and a recognition that different individuals adopt different styles. Context is also considered to be important. So, this research perspective appears to be firmly located within a symbolic sciences paradigm.

There are some other fundamental differences between the four approaches that need to be noted. Firstly, the concept learning, developmental and differential approaches all utilise quantitative methods. This is the most extreme in the differential perspective where achievement tests are predominantly used. Such tests accept a view of science as a fixed body of knowledge which needs to be acquired in order for learning to take place. The differential model is also concerned to identify variables that can be used to explain and possibly predict ability. Quantitative methods and the manipulation of variables are characteristic of inquiry conducted within an empirical-analytic mode.

Secondly, there is an emphasis on the age related studies in the developmental and concept-learning perspectives. In the developmental model, this appears to be premised on the assumption that children of certain ages can all be treated the same and that context is not important. This does not allow for individual differences and patterns of thinking, but assumes that generalisations are possible. In the case of the concept-learning model this is not so restrictive because the purpose is to identify the range of individual differences in concepts. However, the attempt to describe all possible alternative conceptions, also suggests a belief in universal generalisations. The search for generalisations is synonymous with an empirical-analytic paradigm.

Thus, three of the research perspectives (the concept-learning, the developmental and the differential) have a strong empiricist base and elements of an empirical-analytic view of research. The preceding discussion adds credence to the notion that paradigms are not hermetically sealed entities, but that paradigm blending is possible. Only the problem solving perspective appears to be firmly based on other assumptions within a symbolic sciences paradigm.

### **3.5 Approaches to science teaching and learning**

Millar and Driver (1987) identify four common approaches to science teaching and learning, namely a didactic approach, a process approach, a discovery learning approach and an alternative approach. The first three approaches are embedded in an empirical-analytic paradigm.

The didactic approach is concerned with the transfer of information via lectures, demonstrations and the replication of laboratory experiments. The focus is on content and the learning of facts. It is characterised by a transmission mode of learning in which the learners are considered to be passive recipients of knowledge. This approach to teaching and learning is located in an empirical-analytic paradigm in which the acquisition of facts is emphasised.

The process approach focuses less on the view that science is a body of knowledge but emphasises the methods of science. The emphasis is on the use of 'the' scientific method (the hypothetico-deductive method) or on the development of the sub-skills (methods) of science, like observation, measuring, hypothesising, planning and testing. Millar and Driver (1987) are critical of a process approach because it assumes that method is independent of context and can readily be transferred



to new situations. Similarly, Hodson (1988, p 19) adds that 'research fails to yield clear and consistent conclusions about courses which placed greater emphasis on method'. This view of science education is also clearly embedded in an empirical-analytic paradigm in which scientific method alone is emphasised.

The third approach to science education which Millar and Driver (1987) describe is a discovery learning approach in which both the content and the methods of science are combined so that learners are able to 'discover' knowledge through the application of the scientific methods. The intention is that students would discover the facts of science by replicating the experiments done and methods used by scientists. Hodson (1988) suggests that children need a prior conceptual framework if they are to discover anything. This is neglected by advocates of discovery learning. Clearly, this approach is also firmly located in an empirical-analytic paradigm as emphasis is laid on the acquisition of 'correct' facts through the application of 'correct' methods.

The fourth approach which they present as an alternative is widely known as a constructivist approach to science education (Osborne and Freyberg, 1985; Driver and Oldham, 1986; Scott, Dyson and Gater, 1987). Within this approach it is accepted that knowledge is personally and socially constructed by the learner. Thus, knowledge is subjective, rather than objective and theories are provisional accounts of phenomena and relationships. Within this alternative approach it is suggested that learners need to be engaged in activities and processes which seek to challenge and change their existing notions. The learner must therefore be actively involved in the process of constructing and reconstructing knowledge. It is also suggested that learning be 'set in contexts of current or future interest and use' (Millar and Driver, 1987, p 57). Different views and opinions are

respected and given status in the learning situation. This view of science education is embedded in a symbolic paradigm as emphasis is placed on the construction of meaning.

The criticisms lodged by Matthews (1992, p 302), cited in chapter two (p 48), must be noted when constructivism becomes a process of 'leading children to the correct scientific answer'. Solomon (1994, p 12) articulates this problem as a paradox, that constructivist teaching from one view 'reinforces constructivist theory' (that children can construct and reconstruct knowledge through social interactions), but 'from another, teaching is found to be irreconcilable with it'. Here she is alluding to the problem of accepting the relativity of the multiple interpretations of phenomena within the same pupil or between different pupils. Constructivism by its nature allows for the creation of multiple meanings and interpretations. She highlights this paradox by quoting from Von Glaserfeld (1983, cited in Solomon, 1994, p 14), who said 'So the paradox is that in order to find out if our understanding is 'true' we would have to know what we were trying to understand before understanding it'. She notes that part of the problem with constructivism in the science classroom is that it (constructivism) has been built on the notion of 'the pupil as already a scientist (p16)'. Thus, it has been assumed that children are able to negotiate scientific knowledge in the same ways undertaken by the scientific community. So, the fundamental question is whether a constructivist paradigm is possible in science education, given the dominant approach to the practice of science which is located within an empirical-analytical paradigm.

### 3.6 Priorities in science education

Atkin and Helms (1993, p 3) highlight five key areas in science education around which there is ‘unmistakable consensus (p 3)’. These are that:-

... ‘Major concepts of science be stressed.(p5)’

... ‘Breadth of coverage should be replaced by studies in greater depth.’ Here they adopt the slogan that ‘less is more’ (p 5).

... ‘Science necessitates active investigation by the student and clear communication about the processes and results (p 5).’

... ‘Complex levels of analysis and problem solving characterise science (p 5).’

... ‘Multi-disciplinary and inter-disciplinary approaches are becoming more prominent features of science’, involving cross-disciplinary themes (p 5).

These commonly agreed priorities are not surprising. The first four are located in an empirical-analytic paradigm with a pared down emphasis on content and scientific method. The latter priority is the only one that begins to challenge the epistemological boundaries of the traditional disciplines. However, even here, Atkin and Helms (1993, p 6) acknowledge ‘that thematic approaches to instruction are relatively untried and definitely under-investigated’.

Atkin and Helms (1993) go further to suggest other emerging directions for science education. Firstly, they note that science is embedded in a social context and is influenced by both the political and historical context in which it is embedded. Thus, they accept that science is not value-free and is necessarily subjective and suggest that this needs to be taken into consideration in science classes.

They are particularly concerned that science should adopt a practical approach. By this they mean practical in the sense of ‘phronesis, acting wisely in practical matters’ (p 13). They are concerned that children be encouraged to study ‘real’ problems and suggest ‘defensible action that might be taken to ameliorate certain conditions’. These views are akin to a social sciences paradigm and the concern for a practical interest outlined by Grundy (1987). They make some suggestions as to how practical reasoning might be encouraged in the science class.

A further direction they advocate is that of developing ‘habits of mind’ in which children are encouraged to become ‘scientifically enabled citizens’ (p 15), with the capacity to act critically. After Prewitt (1983, cited in Atkin and Helms, 1993, p 15) they argue that ‘the scientifically savvy individual understands fundamental principles that allow him or her to function successfully in the political process, in policy-making decisions, and in issues that effect social change’. This means that individuals understand the positive and the negative aspects of scientific and technological innovations and are able to make informed decisions. This is a political role and is located in a critical sciences paradigm.

Thus, Atkin and Helms (1993) have found a role for science education that can be located in each of the paradigms previously described. Perhaps this is another example of paradigm mediation suggested by Hassard (1993).

### **3.7 Dominant concerns of three curriculum orientations**

Gough and Robottom (1993) describe three curriculum orientations, after Kemmis, Cole and Suggert (1983, cited in Gough and Robottom, 1993), that are adopted in Australian schools. These are a vocational neo-classical, a liberal-progressive and a socially critical approach. They describe each with respect to several factors. This is reproduced in table 3.

A vocational neo-classical approach to education has as its purpose the preparation of students for work. Subjects are fragmented into bits of knowledge to be acquired through a passive transmission and highly structured mode. This orientation is synonymous with a transmission orientation as elaborated by Millar and Seller (1985) and is clearly premised upon an empirical-analytic paradigm. The acquisition of existing facts is a central concern and students are expected to be passive recipients of these products.

The liberal progressive orientation is concerned to prepare pupils to meet the challenges they will face in life. It is accepted that students should be part of the learning process if they are to internalise and make use of the knowledge they acquire. This curriculum orientation represents a move away from the vocational neo-classical orientation as students needs are recognised and subject matter is issue based or involves process skills which students need in order to engage with the world. However, no consideration is given to who decides on which issues will drive the curriculum. Also it is assumed that through the acquisition of appropriate skills, with an apparent emphasis on social skills, students will be able to become good citizens. No consideration is given to how skills or knowledge should be used in order to attain this objective. Thus the emphasis

appears to be on good citizenship, rather than on developing appropriate plans of action. For these reasons, this orientation has ties to an empirical analytic paradigm.

A socially critical orientation is clearly tied to a critical sciences paradigm in which it is accepted that knowledge should be used in order to engage in critical thinking and action. This is geared to highlighting the historical and political aspects that are inherent in society, and to taking appropriate action. Knowledge is acquired through the involvement in real issues and plans of actions. Also, it is assumed that education should have a link to the local community and its issues.

Table 3: Dominant concerns of three curriculum orientations

	<b>VOCATIONAL NEO-CLASSICAL</b>	<b>LIBERAL PROGRESSIVE</b>	<b>SOCIAL CRITICAL</b>
School concern	Preparation of students for work	Preparation of students for life	Engagement of students in critical thinking and action
Dominant school concern	Course or subject content Structuring learning	Issue or process Facilitating student learning	Critical theory and group processes Action oriented
Focus for expression of concern	Faculty and subject organisation	Total school teaching team	Teaching team, students and community
Frequency of concern	Episodic (e.g. prior to course construction)	Ongoing	Ongoing
Themes of concern	Student discipline, teaching resources, curriculum packages, testing procedures. Developing diligent obedient students	Student participation, group process, small group management, programme review. Developing caring, co-operative environment	Student action, group processes and community links, negotiating tasks. Developing working knowledge and critical perspective on society

(after Kemmis, Cole and Suggert, 1983, cited in Gough and Robottom, 1993, p 306)

Gough and Robottom (1993) are firm advocates of a socially critical orientation, being highly critical of the other approaches which are common in Australian schools.

### **3.8 Paradigms in the classroom**

The previous discussions have implications for the analysis of science as undertaken in classrooms by teachers and pupils. It can be suggested that the nature of teaching and learning will depend on the paradigm(s) within which teachers and learners are framed. This will drive their concomitant ontological, epistemological and methodological positions.

Benson (1989) notes that a teacher's epistemological framework impacts on what is taught and how this is taught in the classroom. His research showed that teachers in his case studies all adopted a traditional or positivist view of the world. This included their beliefs about the nature of science where they assumed that the hypothetico-deductive method and the systematic testing of hypotheses are the only valid ways of gathering knowledge. Their views were also translated into the ways in which they interacted with pupils because all teachers adopted text-based and teacher centred methods. Thus, teachers adopted traditional views about the nature of knowledge, about the purpose of science education and about the relationship between the teacher and the learner.

Cronin-Jones (1991) and Gallagher (1991) also show that science teacher's epistemological assumptions impinge on their views of the learner and on their role in the classroom. Teachers tend

Cronin-Jones (1991) and Gallagher (1991) also show that science teacher's epistemological assumptions impinge on their views of the learner and on their role in the classroom. Teachers tend not to understand the processes of science and the ways in which science is developed and validated in society. The consequence is the over emphasis of facts in classrooms. Similarly, Hodson (1988, p 20) attributes the failure of many courses to '(i) Teacher's own inadequate views about the nature of science, (ii) A degree of confusion about the philosophical stance implicit in many contemporary science curricula'.

Eylon and Linn (1988) have also shown that the learner's epistemological views are a strong determinant of their ability to perform in science. For instance, children hold existing views of the world that are resistant to change. These views frame subsequent learning.

Clearly, world views impinge on classroom practice. Hodson (1988) suggests that the most significant factor determining students' attitudes to science are teaching style and the teacher's own image of science. If we are to understand the effects of such determinants more fully, it is necessary to unravel some of the assumptions about teaching and learning in the different paradigms.

For instance, Benson (1989) elaborates some of the values, ideas and views he would expect if teachers were to adopt a constructivist view of science teaching. Millar and Driver (1987) also describe several characteristics of teaching and learning within a constructivist approach. This includes 'negotiating' and 'scaffolding' pupils' ideas (Driver, *et al*, 1994) with the emphasis on the dialogic interactions between teachers and pupils, pairs of students, small groups, the whole class and the comparison of ideas with the scientific community (Yager, 1991).



Similarly, Gough and Robottom (1993) elaborate, from a socially critical perspective, a view of knowledge, a view of the nature of the relationship between teachers and learners, and a view of the structure of subjects. These views are different to those advocated by constructivists and by positivists and focus on the involvement of pupils in social issues. Society is treated as problematic and pupils are engaged as active social actors, identifying and undertaking appropriate social action.

### **3.9 Developing a framework for analysis**

It is clear that teachers' world views, whether held implicitly or explicitly impinge on what happens in the classroom. Similarly, the underlying assumptions about education, about teaching and learning, which are located within a particular paradigm, will determine the nature and process of curriculum development. In order to further analyse trends in curriculum development and emphases in primary science education, a framework for analysis has been constructed. This draws on the three paradigms and compares each with respect to a set of key determinants. These determinants have been selected from a range of possibilities (Rogan and Luckowski, 1990; Hass, 1983) and include some of those used by the authors described in this chapter. The determinants selected are:-

view of knowledge (epistemology),

view of curriculum,

purpose of education,

purpose of science education,

view of learner,

view of teacher,

methods,

content and

assessment.

This is presented in table 4 which provides a composite analytic tool that can be used to analyse various aspects of curriculum, including classroom practice, major curriculum trends in science education and curriculum and policy documents, through documentary analysis. This tool provides the framework for further analysis in chapters four and five.

Table 4: Views of teaching and learning within different paradigms

	<b>EMPIRICAL-ANALYTIC PARADIGM (TRADITIONAL/POSITIVIST)</b>	<b>SYMBOLIC SCIENCES PARADIGM (CONSTRUCTIVIST/INTERPRETIVE)</b>	<b>CRITICAL SCIENCES PARADIGM (NEO-MARXIST)</b>
View of knowledge (epistemology)	Knowledge is independent and external to the observer, acquired inductively and deductively  Realist point of view	Knowledge is personally and socially constructed  Relativist point of view	Knowledge is constructed through social interactions and has historical and political biases which create a false consciousness
View of curriculum	A body of knowledge or a collection of skills	A programme of activities	Curriculum as a 'project', responsive to societal needs
Purpose of education	Transmission	Transaction	Transformation
Purpose of science education	Acquisition of facts and the methods of science, student induction in to the structure of the discipline	Development of scientific concepts, conceptual change	Appreciation of the social reality, and related processes (social, historical, political) Effect appropriate change
View of learner	Passive recipient	Active participant, constructing own knowledge	Active participant engaged in socially relevant tasks
View of teacher	Active transmitter of knowledge	Organiser of learning activities and facilitator of knowledge construction	Active participant, organising necessary resources and activities
Methods	Didactic and teacher centred approaches, e.g. chalk and talk, lectures, text-based work, replication of experiments, demonstrations, empirical observations	Identify existing concepts, expose these to conflict situations, construct new ideas, apply new ideas and review changes	Project work, reflective deliberation, collaborative work, interactive discourse
Content	Lists of facts, sets of skills, separate disciplines	Sets of concepts, themes and relationships	Identified problem or issue oriented, thematic
Assessment	Tests and exams at end of a content section, summative	Diagnostic using drawings and discussions, formative, ongoing	Peer review, profiles, portfolios, collaborative assessment

## **CHAPTER FOUR**

### **INTERNATIONAL EMPHASES IN PRIMARY SCIENCE EDUCATION**

#### **4.1 Introduction**

In this chapter five major emphases in primary science education are examined. These have been derived from a review of the literature since 1983, including selected research journals and books published in the field of primary science education. Each emphasis is described with respect to some key areas, including the purpose of science education, the approach to the teaching and learning of science, the approach to the inservice education of teachers, the approach to materials development, the approach to assessment, and the approach to curriculum development. A critique of each emphasis is also undertaken.

These major emphases are subjected to further analysis utilising the conceptual framework developed in chapter three (table 4, p 77).

#### **4.2 A content emphasis**

Peacock (1993) used the information gathered from 21 countries in the Second International Science Survey (SISS) and from 16 countries in a survey conducted by the National Institute for

Educational Research, based in Tokyo, in order to examine the common topics in primary science curricula. He notes that there is a common core content which tends to be included in primary science curricula around the world. This suggests an international emphasis on science as content or a **correct explanations** (Roberts, 1982) curriculum emphasis at the primary level. In part this is likely to be due to an historical remnant of a eurocentric curriculum. Within this emphasis, the assessment of facts at the end of a course is the dominant mode of student evaluation.

### **4.3 A doing and seeing emphasis**

Peacock (1993) also records that there is a tendency in the curricula surveyed to emphasise the study of the natural environment, whilst the study of the physical sciences and chemistry tends to be left to secondary schooling. He adds that most of the prescribed curricula focus on interactions with observable phenomena and do not deal with underlying science concepts. This suggests an emphasis on inductive methods (observation) in the primary school.

Much of the literature surveyed recommends activities for various topics which children should be engaged in (Cannon and Padilla 1982; Steiner, 1984; van Cleaf and Hamilton, 1988; Barrow, 1989). Many of these reports are just lists of activities to be undertaken and do not examine the way that activities contribute to knowledge formation. The 'hands-on' approach to primary science is based on Piaget's work (Meinhard, 1989) in which it is recognised that knowledge is a cognitive activity and that children are active in constructing knowledge. The emphasis on activities, especially at the lower primary level, is embedded in the view that children need concrete experiences as they are located in the concrete operational stage of cognitive development (Rakow,

1986). However, the common method of implementation of the hands-on approach appears to be an over simplification of Piaget's work because 'while the behaviours of hands-on activity are important, the goal of science education is the development of mental activity' (Meinhard, 1992, p 2). The work of Cohen (1984) supports this observation. He examined the effect of science manipulatives in the development of logical thought in elementary school children and concludes that 'supplying children with manipulative materials does not, in and by itself, appear to be adequate in promoting the development of logical structures' (p 777). He adds that teachers need to be 'more than providers of activities and materials to students' and recommends an active role for teachers in which they encourage children to examine materials from more than one perspective. However, in most of the literature surveyed, children are not viewed as active participants in knowledge construction, but rather as recipients of information through inductive methods.

Similarly, Metz (1995) shows that neither Piagetian nor non-Piagetian research supports the assumption that children in elementary school should only be exposed to 'concrete' activities that emphasise observation and classification. She is also critical of the epistemological messages that this approach conveys to children in their initial experiences of science. She goes on to state that the literature supports the 'feasibility of children's science curricula in which the processes previously approached as ends become tools in contextualized and authentic scientific inquiry' (p93).

The dominant view of the hands-on approach suggests inductivist underpinnings in which activity precedes observation. It is assumed that children will acquire scientific facts by doing and observing science. This might be called **a doing and seeing emphasis** in which concrete activities are

provided, but in which learning might not be consolidated through 'mental activity'. Also, the theory-ladenness of observation needs to be recognised, as primary school pupils will not automatically see what they are expected to see because they bring their existing conceptual framework to bear on the observation process. It has already been argued that an emphasis on content and inductivist approaches are embedded in an empirical-analytic paradigm (pp 28, 29, 55).

This conclusion is confirmed using the conceptual framework for analysis developed in chapter three (table 4, p 77). This shows that a view of curriculum as a body of knowledge; and a view of knowledge as independent and external to the observer and acquired through observation, are located within a traditional paradigm.

#### **4.4 A process skills emphasis**

Harlen (1978) argued that content is relatively unimportant in the primary school and suggested that scientific method should have curriculum priority. This view is consistent with the process approach which has been dominant in primary science education since the 1960s. For instance, the Oregon Department of Education (1988) notes that the launching of Sputnik in 1957 led to a concerted effort to reform science education in America. A number of materials based curriculum initiatives, produced by teams of authors, were undertaken for all levels of the science curriculum during the 1960s. They note that the 'materials attempted to incorporate more of the processes of scientific enquiry and the structure of the disciplines than did textbooks' and 'aimed to place more emphasis on student activity in the laboratory as experimental activity rather than laboratory activity as simple exercises of verification' (Oregon Department of Education, 1988, p 1). Three

elementary science materials initiatives were undertaken in the 1960's, namely 'Science .. A Process Approach' (SAPA), the Elementary Science Study (ESS) and the Science Curriculum Improvement Study (SCIS) (Shymansky, 1989). All three adopted an inquiry approach to science learning, in which Dewey's notion of 'discovery as a method of acquiring knowledge' (Rakow, 1986, p 14) was advocated. Thus, the 'discovery approach of Dewey was re-christened the inquiry approach during the curriculum reforms of the 1950s and 1960s' (Rakow, 1986, p 14).

SAPA specifically adopted an approach that focused on developing the skills that children need to carry out investigations, the so called process skills. These skills are observing, classifying, using space-time relationships, using numbers, communicating, measuring, predicting, inferring, formulating hypotheses, controlling variables, experimenting, defining operationally, formulating models and interpreting data (Rakow, 1986). Process skills are characterised in different ways by different authors, but in general they include the following: observing, raising questions, hypothesising, planning, measuring, interpreting, recording, and critically reflecting (Cavendish, Galton, Hargreaves and Harlen, 1990; Russell and Harlen, 1990). These are considered to be the logical steps which scientists use in their investigations. The process skills approach is one version of an inquiry approach to science teaching and learning and is based on the view that 'by acquiring these skills, students will be able to "do science"' (Rakow, 1986, p 18). Of the three approaches, SAPA is considered by Shymansky (1989) to have produced the least positive results.

In North America the SAPA approach is reflected in much of the literature surveyed, where discovery as a recipe of activities is dominant. SAPA tended to impose 'a hierarchical sequence of hands-on activities under careful teacher direction'. (Wilson and Chalmers-Neubauer, 1990, p 83).



Some recent materials (Williams, 1986; Lindberg, 1990; Lowery, 1992) and teacher preservice and inservice programmes (Alberta Department of Education, 1983; Strawitz and Malone, 1987; Kolesar, 1989) also adopt the approach.

The ESS materials focused on exploring the 'relationship between Man and the environment' using a wide variety of activities and an abundance of hands-on materials (Wilson and Chalmers-Neubauer, 1990, p 71). Essentially children were provided with a wide range of materials on a particular topic and expected to structure and arrange their own activities. Activities were divided into three phases known as circle, triangle and square. During circle, children were expected to work on their own, exploring materials and deciding on what they were going to do. During triangle, the teacher assisted the children by controlling the material available, by asking questions, by providing occasional prompts and by probing for understanding. During square, the teacher was expected to consolidate what children had learned by synthesising information and by defining and explaining concepts. That teachers have found it difficult to adapt to such new roles is evidenced by research undertaken by the National Science Teachers Association. This research suggests that most elementary school teachers have not adopted a process approach and that science teaching is mostly fact and content oriented (Teters and Gabel, 1984).

The SCIS project adopted an inquiry approach to learning that used a three stage sequence referred to as the learning cycle (Rakow, 1986). In this approach the process skills are an integral part of learning in which students used the process skills to discover knowledge. Process skills are not explicitly taught. The learning cycle involves (i) an exploration phase in which children are given unfamiliar materials and told to 'find out everything they can about the materials' (Rakow, 1986, p

210), (ii) a concept introduction phase in which concepts are defined or 'invented' in terms of the experiences children have had with the materials, and (iii) a concept application phase in which the new concepts are applied to new situations.

Several of the studies surveyed adopted a learning cycle model to teaching and learning in classrooms in and for inservice teacher programmes (Garver, 1983; Lawson, 1986; Lawson, 1989; Barman, 1989). Whilst this approach has been popular in development initiatives, Rakow (1986) states that 'teachers increasingly are abandoning this (inquiry) approach and moving back to a textbook-centred approach to teaching science' (p 27). Mechling and Oliver (1983) in an article entitled 'Who is killing your science program?', provide this obituary to SCIS:-

'SCIS. Born 1957; died 1981. Sired by Sputnik and born of the National Science Foundation, the program flourished during its infancy and childhood. Its later years were plagued by inflated equipment costs, failure to provide inservice programs for teachers, and lack of leadership. Killed by stagnation'

Mechling and Oliver (1983, p 16)

They add a number of other reasons for the failure of this science programme, including the fact that teachers were made to 'swallow' (p 16) many science programmes without having any say in their development, selection or implementation.

All three approaches had a strong emphasis on science as a method of inquiry, of discovering knowledge by inductive and deductive methods. Hands-on activities were also an important component in all three. In ESS materials, students assumed the role of scientist, acquiring content knowledge inductively. The SAPA materials focused on developing process skills and presenting

information hierarchically and deductively. In the SCIS approach concepts were presented in ‘an inductive-deductive practice sequence of instruction (Wilson and Chalmers-Neubauer, 1990, p 72).

Several other examples of inquiry based approaches to science at the elementary level in the United States of America were also found, including some large scale, national science programmes. For instance, Barber, Bergman and Sneider (1988), developers of the Great Explorations in Math and Science (GEMS) materials, state that ‘research studies from all over the world have confirmed the general educational effectiveness of the "learning by doing" approach to science and mathematics education, which is at the heart of the "guided discovery " method’ and they cite several studies to confirm their observations. The GEMS materials are based on the same approaches as those of SCIS and the authors advocate a ‘hands-on, minds-on’ approach to learning (p 18). The authors also promote the learning cycle approach. However, they suggest that this is combined with a constructivist approach through asking questions, doing activities, classroom discussions, co-operative learning and real world applications. Without examining the GEMS materials, the extent to which the constructivist approach is married to other approaches is not clear. The approach certainly does not commence with an examination of pupils’ existing conceptions which is central to the majority of constructivist approaches to learning.

Similarly, Science and Technology for Children (STC) (National Science Resources Centre, 1994) based at the Smithsonian Institute in Washington advocates ‘inquiry centred curriculum units that have been carefully designed to involve children in hands-on investigations of scientific phenomena, enabling them to make their own discoveries’ (p 4). The principles on which this is based is that children learn best through an ‘experiential environment where they can investigate science

phenomena using concrete materials' (p 4). They also advocate an inquiry, learning cycle approach that is in harmony with a constructivist learning model. However, this is not made explicit in the curriculum documents which seem to advocate a straight activity based programme, with an emphasis on process skills, and again the prior learning of pupils is not referred to. Thus, the extent to which constructivist approaches are included is not clear.

In the United Kingdom, in the early 1980s, another initiative gave impetus to the process view of science. A concerted effort was made to assess pupils' process skill abilities. This research was undertaken by the Assessment of Performance Unit (APU) which produced a vast number of assessment tasks and used these in large scale surveys, in order to produce an assessment framework. In the design of the framework an attempt was made to separate the assessment of 'the process activities from the understanding of science concepts to allow some measure of independence of judgement of performance on these two key facets of science' (Murphy and Gott, 1984, p 6). This is based on an assumption that the skills of science can be separated from the context and the content. A number of reports were produced by the APU detailing pupils' process skill abilities and attitudes to science at different ages (Harlen, 1983; Harlen, Palacio and Russell, 1984; Murphy and Gott, 1984; Gott and Murphy, 1987). Some of the findings of this research showed (i) that older children performed better on more complex process tasks, like planning investigations, (ii) that there was a higher performance on general skills than on scientific skills, (iii) that children enjoy and are eager to be involved in science activities, (iv) that girls at age 11 tend to perform better on recording and in making observations whilst (v) boys were better at using measuring instruments and recording quantitative results. It was suggested that the results have implications for practice and several recommendations were made relating to ways in which

teachers could specifically address problem areas, e.g. that 'girls may need more encouragement to take an **active** part in science activities, especially in using equipment and making measurements' (Harlen, 1983, p 13). Again the emphasis is on doing, rather than understanding science and a number of ways to enhance children's enjoyment of science are suggested.

Schilling, Hargreaves, Harlen and Russell (1990) recognise five main purposes for assessment, namely (i) for feedback to children, (ii) for finding the starting point for teaching, (iii) for appraising and reporting individual progress, (iv) for reviewing class and school performance and (v) for research and national monitoring. The Science Teachers' Action Research (STAR) Project on which they report was essentially concerned with finding the starting point for the teaching of process skills to pupils. Thus the function was essentially formative (Russell and Harlen, 1990). Teachers worked together at interpreting the results of childrens' abilities in order for an 'exchange of ideas about how children's development of these skills could be fostered' (Schilling, Hargreaves, Harlen and Russell, 1990, p 20). The concern here was for individual action, by teachers in their classrooms, to be able to support children's learning processes.

The above role for assessment is in contrast to the national surveys conducted by the Assessment of Performance Unit which, whilst making some recommendations about teaching, were primarily concerned with research and monitoring and the development of a national framework. This has subsequently been translated into a national assessment programme that runs alongside the national curriculum. This includes the administration of standard attainment tasks, developed by the government, at the end of each key stage (level) of schooling. No consideration is given to differences in abilities in different contexts. Torrance (1991) notes that there is a further

contradiction in this, that by trying to raise national standards through national assessment, the government is denying teacher professionalism and ‘parallel debates about school accountability which largely revolve around demands for the publication of simple indicators of educational output’ (p 538).

Some authors argue that process skills, like concepts, are age related (Berger and Pintrich, 1986; Archenhold *et al*, 1989) and can be acquired as a hierarchy of skills (Russell and Harlen, 1990).

This means that pupils are able to perform different skills at different ages and that there is a progression in ability with age. Thus, Archenhold *et al* (1989) suggest that these skills are built into the curriculum as a progression and that they are specifically taught at different levels of schooling.

As a result the progression of process skills is reflected in the national curriculum in the United Kingdom (Department of Education and Science, 1989). Again, the assumption is that specific skills can be taught at specific ages, without consideration of context and content.

There are four basic language skills, namely listening, talking, reading and writing. (Casteel, 1994) suggests that these are a conduit between language and science. She adds that ‘the literacy processes are the means by which science content is learned because content information is rooted in written and oral languages’ (p 540). She shows how the language skills can be directly related to the process skills of science. Table 5 replicates her comparison.

This comparison suggests that science should not be separated from language. However, a traditional view of science is accepted in which science is seen as a body of content and a method of inquiry.

Table 5: A comparison of the science and literacy process skills.

<b>SCIENCE PROCESS SKILLS</b>	<b>LITERACY PROCESS SKILLS</b>
questioning hypothesising gathering/organising data drawing conclusions analysing data reporting	purpose setting predicting organising ideas constructing/composing evaluating/revising comprehending/communicating

After Casteel, 1994.

The process emphasis is still in evidence in the 1980s and 1990s and is reflected in a large number of books on primary science education which are used in developed and developing countries (see for example Young, 1979; Rakow, 1986; Harlan, 1988; Schilling, Hargreaves, Harlen and Russell, 1990; Cavendish, Galton, Hargreaves and Harlen, 1990; Russell and Harlen, 1990; Peacock, 1986; Harlen and Elstgeet, 1992; Goldsworthy and Feasey, 1994; Smith and Peacock, 1995).

Jenkins (1992) notes that the ‘assumption underlying the so-called ‘process approach’ to school science is that pupils learn best by behaving as scientist themselves’ by replicating the processes that ‘constitute the practice of science’ (p 229). Thus, the process approach is premised on the notion that pupils should learn the way that scientists work and that they should replicate these skills.

Jenkins (1992) is critical of this view.

Whilst several authors recognise that process skills are not used in isolation, but during the course of an investigation (Smith and Peacock, 1995; Schilling, Hargreaves, Harlen and Russell, 1990; Peacock, 1993), they still tend to promote the teaching and assessment of process skills as isolated entities. This continues to promote the view that skills are independent of the context or problem being solved and that they can be explicitly taught. This is questionable. Millar and Driver (1987) are critical of the process approach to science education as the assumption is made that there are generalisable scientific methods and that skills are transferable from one context to a new one. That there are different lists and approaches to classifying process skills suggests that there is no one scientific method and that even within science there are multiple ways in which knowledge is generated. It needs to be recognised that process skills are action words or verbs and in this way embrace a number of different skills oriented at (i) interacting with the world, (ii) thinking about the world and (iii) communicating about the world. Such skills are neither linear nor hierarchical.

Millar and Driver (1987) also note that many authors tend to 'blur the distinction between the way scientists work and the way children learn' (p 38). The assumption appears to be that the two occur in the same way. Whilst some of the process skills used are cognitive skills (e.g. comparing and contrasting as part of observing), others are peculiar to the practice of science (e.g. hypothesising, fair testing).

Thus, Hodson (1988) notes that there is little evidence that science education programmes which have adopted a process approach have actually been successful. This conclusion is in conflict with some advocates of inquiry based or discovery learning (Bernie and Ryan, 1984; Shymansky, 1989) who argue that these approaches 'outperformed their traditional elementary school counterparts'



(Shymansky, 1989, p 33) and were better than traditional textbook courses. However, it must be noted that this is not so surprising as they were assessing that which they were promoting, process skills, attitudes to science, analytic and related skills, and spatial relations (Oregon Department of Education, 1988). Thus the results showed that the process approach was better than traditional text-based and content driven programmes. The evaluations of inquiry based programmes were not concerned to assess pupils' conceptual understanding in science and so the research does not indicate the extent to which children actually understood key scientific concepts. That they were better at performing in the process skill domains is not surprising.

It has already been argued in chapter three (p 55) that the curriculum emphasis of **scientific skill development** (Roberts, 1982) is embedded in an empirical-analytical paradigm in which the dominant concern is acquisition of the scientific method.

The above conclusion is supported when analysing the process approach using the conceptual framework developed in chapter 3 (p 77). The dominant concern is for the acquisition of the process skills as a method of inquiry and for the induction of students into the structure of the discipline. The implicit epistemological assumption is that knowledge is independent of the observer and can be acquired inductively and deductively. Curriculum is seen as a set of skills to be obtained.

Most of the programmes examined did perceive a role for the teacher as more than as a transmitter of knowledge. There was a move towards teachers being facilitators and supporters of children's learning. Also, a fundamental premise of the process approach is that children must be actively involved in hand-on activities. That there is a move to more participative processes suggests

elements of a symbolic sciences paradigm, providing further evidence for paradigm mediation. However, that teachers have found it hard to adapt to this new role suggests that they have not been able to reformulate their own epistemological assumptions and paradigmatic world views.

The approaches to the assessment of process skills has tended to reinforce the view of skills as isolated entities. Thus, skills are often considered as content to be learned. This also suggests a more traditional paradigm and so it can be concluded that much of the work in primary science has, to date, been embedded in an empirical-analytic paradigm.

#### **4.5 A conceptual change approach**

An analysis of the literature shows that the major emphasis in research on primary science education since 1983 has been on childrens' conceptions in various scientific topics. Of 192 journal articles surveyed, 71 (37 %) were concerned with childrens' concepts and with constructivism (teaching and learning) in the primary science classroom. Similarly, of 151 research reports, monographs, conference papers and books surveyed, 75 (49.7 %) were concerned with childrens' ideas in science and with constructivism in the classroom. Of these, the bulk of the research has been conducted in so called developed countries, with only 2 reports from developing countries, namely Nigeria (Urevbu, 1984) and the Philippines (Acuna, 1982).

Childrens' ideas in science have variously been called misperceptions, stunted perceptions, mistranslations, confused conceptions, lost conceptions and true misconceptions (Smith, 1984). Abimbola (1988) advocates the use of the term alternative conceptions because other terms are

rooted in the epistemology of empiricism. Thus, he distinguishes between two kinds of researchers concerned with conceptual change, namely researchers with a revolutionary perspective and researchers with an evolutionary perspective. He notes that revolutionary researchers are less tolerant of alternative concepts and are concerned to change them to the accepted scientific view through instruction. He adds that 'the negative connotation of the terms used to describe students' knowledge that is not consistent with science knowledge, move the perspective close to empiricism' (p 179). Several of the studies that are concerned with conceptual change could be criticised as being empiricist as a 'revolutionary' approach (using Abimbola's (1988) terms) is adopted. Most studies are not concerned to integrate new concepts with existing ones, but attempt to replace them instead. This again highlights the tension between a constructivist approach to science and the practise of the natural sciences, that was raised in chapters two and three (pp 48, 67).

In contrast, evolutionary researchers tend to 'view prior conceptions as an interpretive framework on which to anchor new learning' and are thus are more concerned with the 'relationship amongst concepts' (Abimbola, 1988, p 179) and ways in which they can be integrated. Such research is concerned with developing pupil's understanding of concepts. Howard (1989) draws on schema theory to elaborate a view of understanding and conceptual integration. A schema is a mental representation of the relationships between a set of concepts. He states that 'any scientific theory can be regarded as a schema, as a mental representation used to make sense of some part of nature' (p 117). Rumelhart (1984, cited in Howard, 1989) lists three circumstances in which pupils will not understand. Firstly, if pupils do not have an appropriate schema into which new material can be assimilated, secondly if a person knows the appropriate schema but cannot elicit it in that context or

thirdly, when a person has competing schema which get confused. Howard (1989) goes further to elaborate some approaches that teachers can use to build student's schema, dependant upon each of the above cases. Similarly, Pines and Novak (1985) used concept propositional analysis to examine children's concepts before and after instruction. 'Propositions are two or more concepts linked semantically to express specific relations between the concepts' (p 225). This is another example of an attempt to understand the nature of the relationship between sets of concepts rather than a categorisation of individual concepts into misconcepts / alternative concepts, an so on. Thus, evolutionary researchers are more concerned to reconcile new concepts with existing concepts as opposed to trying to replace the prior concepts. The evolutionary view is clearly embedded in an interpretive paradigm in which understanding is a key facet and goes some way to reducing the criticisms of constructivism cited in chapters two and three (pp 48, 67).

Hashweh (1988) calls for the distinction between three kinds of studies of childrens' conceptions in science, those that are purely descriptive, and research that seeks to "test" the explanatory studies or that attempt to induce conceptual change' (p 122). In the literature surveyed, the majority of articles (76 %) fall into the first category, i.e. descriptions of childrens' ideas of various science concepts. The alternative conceptions described include physical concepts like the particulate nature of matter (Comber, 1983), energy (Urevbu, 1984; Ault, 1988; Ross, 1988), earth and gravity (Sneider and Pulos, 1983), earth in space (Osborne, 1991), light (Watt and Pope, 1989), chemical concepts (Gabriel, 1989) including molecules (Ault *et al*, 1984), and biological concepts like classification (Trowbridge and Mintzes, 1985), plants and photosynthesis (Eaton, 1983; Smith and Anderson, 1984a), living and non-living things (Joyce and Peacock, 1993) and so forth.

Some studies of childrens' alternative conceptions go further to recommend teaching activities that could be used to develop or change student conceptions (Minstrell and Smith, 1983; Osborne, 1984; Riddle, 1988; Varda, 1989). However, the notion that pupils only need to perform certain activities in order to change or develop new concepts is simplistic as it is premised upon inductivist assumptions which suggest that children can change their ideas by doing and seeing.

Only a few studies actually examined whether the suggested instructional strategies enhanced concept formation (Osborne, 1983; Stavy, 1984; Cross and Pitekethly, 1988; Solomon, 1983). Hashweh (1988) is critical of this and this is why he calls for the distinction between types of research. Only a few studies fit into Hashweh's second category and attempt to explain or identify the origins of alternative conceptions (explanatory research) (Head, 1986; Gabel, 1989). For instance, Gabel (1989) suggests that 'there are three obvious ways that persons acquire misconceptions' (p 727). She suggests these are (i) through the interpretation of everyday events, (ii) from the difference between the use of everyday language and scientific language and (iii) from teaching that presents concepts beyond pupils' developmental level or when children are presented concepts in too few contexts.

Some studies that fall into Hashweh's latter category show that conceptual change is possible (Stavy, 1984; Cross and Pitekethly, 1988), but that childrens' ideas are often resistant to change, even after instruction (Watt, 1980; Solomon, 1983; Berliner and Casanova, 1987). In some cases there is in fact no change after being taught specific concepts (Smith and Anderson, 1984). A large scale project, called the Science Processes and Concept Exploration (SPACE) Project, was initiated to find out pupils' ideas before and after instruction in a number of topics. The research

was undertaken by the Centre for the Advancement of Science and Technology (CRIPSAT) at the University of Liverpool. Topics covered include electricity (Osborne, Black, Smith and Meadows, 1991), evaporation and condensation (Russell and Watt, 1991), light (Osborne, Black, Smith and Meadows, 1990), sound (Watt and Russell, 1990), growth (Russell and Watt, 1990) processes of life (Osborne, Wadsworth and Black, 1992) and materials (Russell, Longden and McGuigan, 1991), amongst others. The results of the research confirm the conclusions of other researchers.

Some research indicates that concepts are related to children's developmental stage and develop over time (Sneider and Pulos, 1983; Lawson, 1988; Adams, Doig and Rosier, 1991). This is also known as progression (Driver, 1992). The research undertaken by CRIPSAT confirms the progression for many concepts and topics in science. Masters (1994) adds that, internationally, research is showing that there are a limited number of alternative concepts on a particular topic. However, most of the research cited is from so called developed countries and there is little information available on childrens' alternative conceptions in developing contexts. It is conceivable that the different languages and cultures in these contexts will have an effect on conceptual development and that other conceptual variations are possible.

The inseparable relationship between language and thought was established by Vygotsky (1967). It is also clear that language is a social activity intended to convey meaning about certain events or social conditions. Osborne (1993) suggests that 'teaching science needs to place more emphasis on linguistic explorations which provide an opportunity for the child/student to develop proto-concepts that enable thinking' (p 117). McGuigan (1990) shows that children may confuse everyday terminology with scientific terminology. Here the emphasis is on labelling and not on

how children use language to mediate their conceptual growth and so her research does not go far enough. This is a very restricted view of language, seen only as a tool for labelling correct facts and so is located in a traditional paradigm. Similarly, in the literature surveyed, there was little concern for the role that language plays in conceptual development at the primary school level. A concern for the ways in which language is used in understanding scientific concepts would be located within an interpretive paradigm. This is undoubtedly an important area for further research.

Whilst the bulk of the research has focused on childrens' ideas in science, some researchers have examined teachers' scientific concepts (Kruger and Summers, 1988; Kruger, 1989; Kruger and Summers, 1989; Neale, 1990). The scientific concepts of preservice teachers have also been investigated (Shaw and Cronin-Jones, 1989; Gabel, Samuel and Hunn, 1987; Fleury and Bentley, 1991; Galili, 1993). These studies show that many teachers also hold alternative conceptions in many science topics.

Clearly, the research into childrens' conceptual development and teachers' concepts has implications for several aspects of curriculum including, approaches to teaching and learning, preservice and inservice education of teachers, materials and textbook development, curriculum and syllabus development and curriculum evaluation. Each of these will be briefly discussed.

A number of conceptual learning models, based on constructivist principles, have been promoted. These include a step-by-step approach (Watson, 1994), a generative teaching model (Harlen and Osborne, 1983, Cleminson, 1990), a three dimensional model (Anderson *et al*, 1991) and a generalised model for a constructivist teaching sequence (Scott, Dyson and Gater, 1987). The latter

is the model used by the Children's Learning in Science Project based at the University of Leeds in the United Kingdom. This model is the one most commonly referred to. It is a five stage model involving orientation, elicitation of ideas, the restructuring of ideas, the application of ideas and the review of the change in ideas. Constructivist approaches characteristically have some similar elements that involve the identification of alternative conceptions, provision of the opportunity to challenge these concepts and the development of new concepts. These elements are reflected in many of the articles which advocate strategies for dealing with particular concepts.

Within a constructivist approach, the teacher's role is that of a facilitator of 'conceptual change by encouraging pupils to engage actively in the personal construction of meaning' (Driver and Oldham, 1986, p 116). This has been elaborated in chapter three (p 67). A similar role is perceived for the primary school teacher in the literature surveyed. Minstrell and Smith (1983) also argue that the role for the teacher is that of a diagnostic specialist, able to identify and challenge pupils' ideas. In a comparison of three different approaches to teaching, Roth (1989) argues that a conceptual change approach had the biggest impact on pupil thinking. Anderson *et al* (1991) add that children rate lessons that are closer to a constructivist approach more highly than traditional lessons.

There is very little in the literature on concept formation and constructivism that deals with assessment. It can be accepted that the elicitation and identification of pupils' ideas prior to instruction is a form of formative assessment that is used to develop teaching strategies. In this way assessment becomes an ongoing process (Watkinson, 1991; Harlen, 1993). However, there is very little information on the other purposes of assessment. Noori (1993) notes that for many years the



emphasis of assessment at the primary level has been embedded in a positivist-quantitative paradigm. She suggests the use of authentic assessment in which a variety of assessment strategies are used to assess pupils' understanding of scientific concepts. In this way assessment becomes a tool for teaching and not merely an instrument of measurement. Authentic assessment might include pupil portfolios (Swang, 1993) in which examples of a pupil's best work are placed, thereby giving an indication of what is valued. Swang (1993) also advocates the distinction between work portfolios and exhibit portfolios. Pupil profiles and records that include discussions with individual pupils, discussions with their parents, detailed observations in science lessons, as well as a diary of observations across the curriculum (Barr, Ellis, Hester and Thomas, 1988) are also examples of alternative forms of assessment that are less quantitatively oriented and so give more insight into whole pupil performance. Harlen (1993) adds that there are 'two main ways of arriving at a summary of children's achievement at a particular time' (p 158). The first is by collating a summary of continuous or ongoing assessments and the second is by means of 'checking up through giving some special tasks' (p 159) that are designed to establish if children have developed particular skills or ideas. She also advocates that children be involved in assessment, through forms of self-assessment, so that children begin to understand the purposes of assessment and the expectations being made of them. These are all geared to increasing learner understanding and participation and are clearly embedded in an interpretive paradigm.

There have been some attempts to translate the research on children's and teachers' ideas of science into preservice and inservice programmes. For instance, Gabel, Samuel and Hunn (1987) and Galili (1993) suggest ways in which preservice teachers' alternative ideas about key scientific concepts can be addressed. Similarly, Stoddart *et al* (1993) advocates the use of a conceptual

approach to the teaching of elementary science and mathematics teachers. They show that a conceptual approach is effective in improving novice teachers' understanding of subject content.

Similar studies of teachers who are already teaching are limited. Most studies, some of which have already been described previously in this chapter, simply list teachers' alternative conceptions, but do not examine how these can be mediated. In one study, Barnes and Barnes (1989) examined teachers' ideas before and after a two week inservice course that aimed to address teachers' misconceptions. They note that some teachers 'corrected' their misconceptions, whilst others adhered to their original misconceptions or changed them for a new misconception. This again serves to highlight that many alternative conceptions are resistant to change and that people do not simply change one concept with another. This lends credibility to the view that new knowledge needs to be integrated with existing schema. Based on their studies of teachers' conceptions, Kruger and Summers (1989) add that 'urgent consideration must be given to those teachers who form the backbone of the primary service who do not possess that requisite understanding at present' (p 26). They go on to question whether conceptual science can be taught by teachers who themselves do not understand the science concepts and wonder whether such teachers create further misconceptions in the minds of the children they teach.

In other inservice education programmes, for example the Nuffield Primary Science Project (Nuffield Chelsea Curriculum Trust, 1993a and 1993b), the Urban Network Project in New York (Dyasi, 1995) and the Learning in Science Project (Primary) in New Zealand (Learning in Science Project, 1982), the focus is on promoting a conceptual change approach or model of teaching. In the Nuffield project, teachers are presented with examples of childrens' ideas, with ways to elicit childrens' ideas and teaching strategies to effect conceptual change. However, given that many

teachers themselves have misconceptions, the effectiveness of such initiatives needs to be questioned.

Dyasi (1995) suggests that there are five dominant models of INSET of science teachers in America, namely (i) the immersion model in which teachers are immersed for a period of time in new approaches and theories, (ii) the scientific experience model in which teachers are placed in laboratories with scientists, (iii) the curriculum implementation model in which teachers are trained to implement predetermined packages, (iv) an action research model in which teachers go through cycles of planning, action, observation and reflection and (v) pedagogic knowledge training in which teachers are trained in particular methods and approaches. The latter is the dominant model in America, but Dyasi (1995) advocates an immersion model in which teachers are confronted with alternative views of science and beliefs about learning that are essentially constructivist in nature and focus on meaning making in science. Approaches to teaching and learning are modelled for teachers during their own active engagement in scientific experiences. Action research, classroom based support and the involvement of administrators are also included as key elements of INSET. The value of modelling approaches to science education for teachers during inservice programmes has also been confirmed by Warren, Puttick, Conant and Rosebery (1992). The LISP (Primary) initiative established teachers' action research groups who investigated childrens' ideas and explored and evaluated solutions to specific problems. The action research mode is reported to be a powerful form of teacher development and professionalisation (Gilbert, 1995) because teachers are actively engaged in generating knowledge and in trying to understand their own practice.

Eaton (1983) suggested that research into childrens' ideas should be used as the basis for the design of materials and that such materials should explicitly contrast different views. Evidence for the translation of research into the development of more appropriate materials is limited and only a few examples were found. The research undertaken by the SPACE project based at CRIPSAT in Liverpool has formed the basis of a comprehensive set of materials covering the content of the United Kingdom's science curriculum (Nuffield Primary Science, 1993a and 1993b). No research reports on the effectiveness of the materials were found. Smith and Anderson (1984) compared classrooms (teachers and pupils) before and after the teachers used commercially available materials and then before and after they used modified materials that informed them of pupils' conceptions and suggested teaching strategies. The results showed that when teachers taught using a conceptual approach, more than three times the number of children understood the concepts under investigation. The Michigan State University in America has conducted a number of other similar studies that compare the commercially available text materials from the SCIS programme, which adopted a discovery approach, with alternative materials that adopt a conceptual change approach (Roth, 1985a; Roth 1985b; Berkheimer, 1990a; Berkheimer, 1990b). These examples all show that materials which adopt a conceptual approach are more meaningful than the traditional discovery materials.

It has also been found that many existing texts do not build up three important components of conceptual development, namely connectedness amongst concepts, connectedness to prior knowledge and the usefulness of new knowledge (Eichinger and Roth, 1991). Similarly, Staver and Bat (1989) examined several textbooks commonly used in the United States. They note that most textbooks may be overloading children's working memory capacity and that the 'level of reasoning

required to comprehend the relations between individual concepts within a structure is typically beyond that exhibited by primary-level children' (p 348). They conclude that in developing text-based materials developers need to take into account the 'interactions occurring between the text and the child' (p348) and that consideration should be given to existing concepts and thinking skills. Clearly, there is scope for materials and text development that draws on existing research.

That research is overlooked or paid lipservice was evident in the case of one set of materials (Wilkinson 1994a and 1994b) that the author reviewed (Raubenheimer, 1995a). Even though the author explicitly states that the materials adopted a conceptual approach to teaching, this was not actually evident in the materials. Instead the materials list sets of apparently unrelated activities in which there is no attempt at conceptual development.

The research that has already been outlined clearly has implications for the development of curricula and syllabuses. Urevbu (1984) called for the matching of the curriculum with pupils thinking strategies at different grades. Driver (1988) agrees with this when she says that 'a great deal more thought and research effort may need to go into the choice of appropriate experiences for particular age groups and sequencing over years of the domains of experience' (p 76). She goes further than this by suggesting four questions that need to be considered in developing appropriate curricula. These are:-

- 'What are the domains of experience which children at a particular age are interested in exploring?'
- 'Within these domains, what are the questions children themselves are interested in?'

- ‘What are the domains of experience that will enable children to obtain knowledge that they see as useful to them and which provide useful learning outcomes in themselves?’
  - ‘How might experiences be chosen and sequenced in order that they give students an opportunity in the long term to construct some of the important conceptual ideas in science?’
- (Driver, 1988, p 76).

Thus she is proposing an approach to curriculum development that is built around domains of experience ‘rather than the theoretical concepts of a scientific discipline’ (Driver, 1988, p 77). Driver (1988) goes further to call for curriculum development as a research programme, that is ongoing and developmental.

Whilst there may be recommendations for curriculum development based upon research, it appears that curriculum developers are ignorant of the research or that they choose to ignore the findings. Watt and Pope (1989) are critical of the developers of the National Curriculum in the United Kingdom. They highlight that curriculum developers did not consider the research into children’s ideas when designing the curriculum. They cite the example of children’s understanding of the concepts of light. For instance, the curriculum states that children at age seven must ‘know that light passes through some materials and not others’ (p 329), whilst research shows that children at that age do not know that light passes through anything. Similarly, Russell, Qualter, McGuigan and Ewart (1993) evaluated the United Kingdom National Curriculum documents based on the evidence obtained from their research into pupils’ conceptions in science (see details of the SPACE project based at CRIPSAT, University of Liverpool). The focus of the evaluation was on progression in the programmes of study and the statements of attainment outlined in the National

Curriculum. They also highlight that a number of aspects covered in the curriculum are conceptually too demanding for children at particular ages or levels of the education system. For instance, wave theory is conceptually too burdensome at key stage three. There were also inconsistencies in the conceptual demands made of children at the same level and the progression of concepts from stage to stage was often overlooked. This means that learning experiences that are suggested in the curriculum often become superficial. This evaluation also highlights the lack of consideration of research information in curriculum development initiatives.

Feldman and Atkin (1993) who conducted a survey of major projects in America (e.g. Project 2061 and SS&C) came to the same conclusions. They note that in general there 'seems to be little or no connection between the research done in science education' and the initiation of new science education projects (p 286). Thus, whilst research may be used for evaluative purposes, a far more fundamental use of research for the development of new initiatives seems to be grossly overlooked. A brief survey by the author of the California Science Framework (Californian Department of Education, 1990) and the Australian curriculum profile for science (Curriculum Corporation, 1994) confirm these observations. In the Australian curriculum profile there is no mention of conceptual development and in the Californian document it is restricted to one page of a 220 page document. The Australian profile does refer to progression but this only relates to progression in learning outcomes and it is not clear whether the suggestions are based on research. In both documents there is an emphasis on the scientific method, and the content and processes of science.

Analysing the research presented in this section, by applying the conceptual framework (p 77), it is clear that the conceptual change approach to primary science education is located in a constructivist

paradigm. The underpinning epistemology is that knowledge is personally and socially constructed. Both learners and teachers are viewed as active participants in the learning process. New knowledge can be constructed by building on, developing and changing existing ideas. There is a concern for the links between different concepts and the ways in which children's conceptual schema can be developed. However, it has also been noted that some of the work within the conceptual change emphasis have underlying empiricist assumptions.

Assessment practices, as formative and ongoing activities, also support the conclusion that the conceptual change approach is located in an interpretive paradigm.

#### **4.6 A concept/process-based science**

The Oregon Department of Education (Oregon Department of Education, 1990; Cox, 1990 and Meinhard, 1992) advocates a concept/process based approach to science education, including at the elementary level (Meinhard, 1992). In contrast to the trend that curriculum developers do not generally use research findings, the Oregon Department of Education (Oregon Department of Education, 1990) is eager to use 'research on how learners grow and develop prior to program development and the organisation of instructional techniques' (p 1). The Oregon Department of Education describes five key trends which it uses to substantiate the reorganisation of its science curricula. These are:-

- \* the instructional methods which teachers use,
- \* the curriculum, that is identified as important to student growth,
- \* the learning activities in which students are asked to participate,



- \* the evaluation of student growth,
- \* and placing science in a broader, interdisciplinary context which relates it to societal values (p 1).

For each of these areas the main trends in research are discussed and the implications for science education described. Firstly, the Oregon Department of Education highlights that research is showing that knowledge is an active mental process in which knowledge is constructed. Teaching strategies that utilise problem solving cycles and the thinking processes that students engage in when constructing concepts are most effective. They advocate a seven step learning cycle (Meinhard, 1992) with problem posing as the beginning of investigations with objects. The teachers role is to help with problem posing and formulation of a plan, to provide support during the investigation (e.g. how to go about gathering data), to introduce the language needed to talk and write about the investigation and to develop innovative approaches to evaluation. 'The teachers' task is to help students take ownership and responsibility for organising their learning' (Meinhard, 1992, p 8).

Secondly, the same department also highlights that there is a move away from curricula that lead to recall of knowledge, and that there is increasing concern for curricula to develop the 'intellectual capabilities' of students. This should involve the 'identification of fundamental concepts and understandings, deeper mental processes of reasoning, investigation and problem solving, identification of relations among concepts, and specification of the development of concepts' (Oregon Department of Education, 1990, p 3). The process skills are seen as an integral part of knowledge generation as opposed to ends in themselves. There is also concern that incorrect

concepts are not merely replaced with the correct scientific ones, but rather that there is the development of conceptual frameworks. According to Abimbola's (1988) definitions, the approach adopted is clearly an evolutionary one.

Thirdly, there is a move away from the view that activities are ways to present information or opportunities for children to practice what has already been presented to them. Active learning means the physical **as well as the mental interaction with objects** which aid in the construction of knowledge. Thus the focus is on 'mental rather than observable activity' (p 4). Integrating childrens' experiential activities with their knowledge and ways of organising and representing that knowledge are also key components. Emphasis is placed on co-operative learning so that children are able to construct knowledge about the activities they are engaged in, through interpersonal engagements with their peers. This clearly overcomes the problems already outlined in a straight activity based or hands-on approach to primary science education.

Fourthly, the Oregon Department of Education also recommends a move away from heavily quantitative approaches to the evaluation of student learning (Oregon Department of Education, 1990). Students are encouraged to re-evaluate their investigation at the end of the learning cycle in the light of the evidence they have gathered and the new concepts they have formed. The focus of the evaluation is on tracking how students are actively constructing concepts and using conceptual frameworks, thereby indicating their level of understanding. Thus, evaluation is part of the learning cycle and not an 'add-on at the end of a series of activities' (Meinhard, 1992, p 9). Self-evaluation and peer evaluation are also encouraged.

Finally, the Oregon Department of Education advocates the inclusion in the curriculum of the role of values in science by adopting a Science Technology and Society (STS) emphasis (Hull, 1990; Oregon Department of Education, 1990). The STS trend is embedded in the belief that science is primarily a human process, located in society. Thus, STS is geared to 'directly confronting the real world in all its complexity, and the need to understand the world is raised by problems of human activity in the physical and living environment' (Oregon Department of Education, 1990, p 7). In this way children are encouraged to understand the ways in which science has brought about changes in the world, for better or for worse. The notion that children can be engaged in 'practical, societal values' (p 9) is introduced, and here practical is read in the sense meant by Schwab (1974) as elaborated in chapter three. This is accompanied by an interdisciplinary approach which further promotes the view that science is not a separate discipline with its own facts and methods, but a complex social process.

The Oregon Department of Education is clearly concerned with the development of conceptual frameworks or schema, rather than the replacement of incorrect concepts with the correct ones. The curriculum documents appear to be the most coherent and comprehensive of those surveyed. This has been done by integrating the key trends and elements in science education into a holistic science education programme. However, like most other programmes, the role of language in conceptual development and learning has been neglected. An approach that includes language and process skills and language and conceptual development could be advocated.

Of particular note is the fact that a Science, Technology and Society (STS) focus (Hull, 1990) is encouraged for all levels of the education system, including elementary education (Meinhart, 1992).

Of the programmes and literature surveyed, this is one of the few examples in which an STS approach was advocated for the primary level. The Oregon Department of Education suggests that this is particularly important for generating pupils interest, and for promoting problem solving investigations because children are interested in real-life topical issues (Meinhard, 1992). A number of possible ways in which a Science Technology and Society focus can be introduced are outlined (Hull, 1990). Thus, pupils' learning in science is genuine and motivated by their own interest and enthusiasm. Such action oriented projects have been advocated in the environmental education field in which children become environmental problem solvers (Monroe and Kaplan, 1988). This is in contrast to some of the other studies, including some that advocate constructivist approaches, in which contrived activities for pupils are suggested. Whilst 'real' situations may provide more meaningful learning they are also more difficult for teachers to manage and teachers may adopt more traditional approaches, like picking up litter (Monroe and Kaplan, 1988).

The general approach and the roles advocated for pupils and the teacher indicate that this programme is located in an interpretive paradigm. There appears to be a genuine concern to promote understanding through interactive processes and learning experiences. However, this is extended to providing children with insights into the broader dynamics and issues in society through the promotion of a STS perspective. The intention is not for pupils to unmask the 'myths' in society, which would be the case if a critical paradigm were being promoted, but rather for students to begin to understand the role that science can and does play in society.

#### **4.7 Concluding remarks**

An overview of the main emphases in primary science education has been provided and many issues for curriculum development identified. These emphases have been analysed in terms of paradigms in education and have been related to trends in science education generally. There has been a theoretical move away from positivist approaches, and this is described within the research literature. The international shift has been towards a constructivist approach to the teaching and learning of primary science. None of the approaches at primary school level appear to be located within a critical science paradigm.

It seems that this same shift has not occurred within the majority of teachers' classrooms and that by and large traditional approaches still dominate. As a result, there are many difficulties in implementing a constructivist approach to primary science education in so called developed contexts.

## **CHAPTER FIVE**

### **PRIMARY SCIENCE EDUCATION IN SOUTH AFRICA AND IN OTHER DEVELOPING COUNTRIES**

#### **5.1 Introduction**

The focus of this chapter shifts to the South African context. South Africa is commonly referred to as having a mixture of both developed and developing contexts, but issues relating particularly to the latter context have largely been ignored as a result of the historically discriminatory policies of the previous government. Because of the developing nature of South Africa, issues and approaches relating to science education in other developing contexts, particularly in Africa, are relevant. Thus, an historical overview of curriculum innovations in other developing contexts, including a review of some of the main trends in the recent past, is provided in this chapter. Issues relating to the selection of science content, to materials development, to teacher participation, to the inservice education of teachers, and to systemic change are particularly relevant.

The intention is to provide a backdrop against which developments in South Africa can be reviewed and to generate some key messages for curriculum innovation and change in this country. These messages are drawn from lessons and trends that emerge from

international experience in primary science education (elaborated in chapter four) and from innovations in developing contexts described in this chapter.

Before this can be done, it is necessary to document the recent practices of curriculum reform in South Africa, as well as to review documentation relating to primary science education. This is done in order to locate these within a particular paradigm using the conceptual framework (chapter 4, p 77), to make comparisons to emphases internationally and to highlight the disjuncture between education policy and practice. This will raise an awareness that any new policies and proposals must recognise the constraints of existing theories and practices.

## **5.2 Recent practices of curriculum reform in South Africa**

It is generally accepted that curriculum and syllabus reconstruction are key areas for development in South Africa. Kahn *et al* (1992) have labeled the science syllabuses of the previous government as ‘outmoded, academic, content-driven and decontextualised as there is little attempt to relate the syllabus to the everyday life of the learner’ (p2). They note that for the majority of learners, science is perceived to be a difficult subject which has little relevance to their every day lives and which has to be memorised for exam purposes. The epistemological view of science that is reflected in the syllabuses is a ‘simplistic positivism’ (p 3), emphasizing knowledge as objective and unproblematic, science as a body of facts, and the scientific method as the only valid way of discovering

new knowledge. They add that most teachers do not have the requisite content knowledge nor the pedagogic skills to teach the subject effectively.

Similar criticisms have been leveled at the process of curriculum decision making which was dominated by the 'white' own affairs departments of education and so called curriculum experts. Subject committees were formed to develop draft syllabuses which were then ratified by the 'national' curriculum committee for that subject (NEPI, 1992). These were then sent to the other 'own affairs' education departments (namely, the House of Delegates, the House of Representatives, the Department of Education and Training, and the various Homeland Education Departments), who had been accorded observer status only, for them to 'adjust in terms of their cultural needs' (NEPI, 1992, p 12). The process was therefore non-participatory and did not represent the broader South African community and their needs. The interests of teachers, organised labour, business and civil society were also neglected. Thus, King and Van den Berg (1992, p 14) described the process as that of 'syllabus revision' rather than 'curriculum development' because larger curriculum issues were not considered, and what was done was essentially only a rearrangement of subject content. In the case of the primary science curriculum, two separate committees existed, one for the physical science component and one for the biological component of the syllabus. No attempt was made to integrate these two disciplines at the primary level meaning that pupils developed a fragmented view of the nature of science.



In April 1994, South African elected its first democratic government. In August 1994 a process of syllabus revision was put in place by the Minister of National Education, Professor S Bhengu. The purpose was to 'remove any content that was racist sexist, or otherwise offensive, or which was inaccurate or outdated' (Daily News, 2/2/1996). An appeal was made, via newspaper advertisements, for public submissions and recommendations (Daily News, 4/8/1995). It was made clear, however, that any recommendations should not require the production of new textbooks and materials as there were not sufficient finances for this.

Twenty five field and sub-field committees, and three phase committees were established to consider the public recommendations, to remove inaccuracies and offensive elements, to prune content and to consolidate the various core syllabuses in use. The committees operated under the auspices of the National Education and Training Forum (NETF). A primary science sub-committee was established, operating under the auspices of the natural sciences field committee. Five people served on the committee, none of whom was a primary school teacher, and only one of whom had seen the inside of a Black (African) classroom! Thus, yet again no 'voice' was given to teachers and those for whom the changes were meant to benefit. This observation was not restricted to the primary science group, as Jansen (1995) notes that there were few students and teachers represented, and that 'the dominant, shaping voices in these committees were mainly white and male' (p 8).

The primary science committee met only once, on the 30 September 1994, to undertake the tasks allocated to them. The outcome was yet again a process of tinkering:- some content (the mutual dependence of plants and animals) was moved to standard 6 level; and in order to rationalise the syllabuses in use in different education departments, it was decided that primary science would commence at standard two level. In effect it was the ex-House of Assembly syllabus that was adopted, giving greater status to the white model of education (Jansen, 1995). The latter decision mostly affected Black (African) teachers and children as, historically, science had only commenced at standard three level in their schools, to coincide with the transition from mother-tongue instruction to instruction in English. There were several major consequences of this decision that were not taken into consideration. Firstly, the majority of standard two teachers had never taught science and therefore did not have the necessary pedagogic content knowledge to teach the subject. This left many teachers feeling very insecure about teaching the subject and lacking in confidence in their abilities. Secondly, there are no text books for standard two mother-tongue instruction of science. And the paradox is that if science were to be taught in English, the children would not have the necessary English vocabulary to learn concepts in any meaningful way. Thirdly, no specialised equipment for science has ever been supplied to African junior primary schools, further disadvantaging these already marginalised children. Overall, the process was rushed, decisions were made in a vacuum and so inadequate attention was paid to issues in different contextual realities.

Thus, whilst the process of revision was necessary, it has been criticised by some educators as not going far enough, being cosmetic and a ‘bland and minimalist reform of the apartheid curriculum’ (Jansen, 1995, p 3). Jansen (1995) takes his argument further, saying that it would be naive to perceive the process as simply a technical exercise. He analyses the process in the context of the politics of transition and suggests that the entire undertaking was geared to gaining short-term political credibility, without having to undertake fundamental and substantial change. The process was geared at gaining political ‘points’ without undertaking real innovation.

As already stated, there was virtually no change to the syllabus and so the revised interim core syllabus for general science standards 2, 3 and 4 (Department of Education, 1995a) and for standard 5 (Department of Education, 1995b) is essentially the same as the previous House of Assembly syllabus for general science. Raubenheimer (1994) provided a critique of the previous primary science syllabus, detailing her comments under four key headings, namely, aims and purpose; content; methods; and assessment. Her comments are therefore relevant to the current syllabus documents and are reviewed and elaborated here.

Firstly, aspects relating to the aims and objectives of the general science syllabus will be considered. One of the major aims is to promote the scientific method, and particularly the inductive method (observation and recording of information), which are advocated as important skills for pupils to learn. However, this is not carried through into the subsequent body of content and there is no attempt to elaborate ways in which the

scientific method, or the process skills of science, might be included into the teaching and learning of the subject. Thus, for many teachers who have never encountered the skills of science, this objective is meaningless and cannot be translated into practice. Furthermore, the promotion of only the inductive method suggests a very restricted and narrow inductivist view of science.

There is a strong emphasis on the acquisition of knowledge in the aims. This includes knowledge as ‘the ability to recall’ certain facts and concepts (Department of Education 1995b), knowledge of the ‘correct scientific terminology’ (Department of Education 1995a) and knowledge of ‘the use of appropriate instruments’ (Department of Education 1995b). These aims promote a view of science as a body of facts and a set of skills to be acquired, locating the aims within a positivist paradigm. Any attempt to move beyond this is restricted to the application of such knowledge and skills to ‘other familiar situations’ or ‘new but related situations’ (Department of Education 1995b). There is no attempt to use scientific knowledge and skills developed to solve problems in the broader societal context. Similarly, understanding and meaning making are not included as worthwhile aims.

A strong Christian Nationalist element is still retained, through the objective stated in the standard 2, 3 and 4 syllabus, ‘to recognise the omnipotence of the Creator’ and the standard 5 syllabus, to ‘develop a sense of awe and reverence for the Creator’. Alternative, views about the origins of life on earth are not given any space. Jansen (1995)

notes that this was a major point of discussion in some of the science committees because of ‘its broader relationship to conservative politics’ (p 6) but adds that no consensus was reached and so the clauses were retained.

Secondly, issues relating to content will be discussed. The bulk of the syllabus details the content that teachers are expected to teach. All topics are compulsory and no consideration has been given to needs in different contexts. The content is listed as a set of topics, with sub-topics within each topic. Thus, the syllabus is essentially a long list of facts with no links between the various sub-topics within a topic. There is also no clarity as to why certain topics were chosen, nor any consideration as to how these relate to other topics in the syllabus. An addendum to this is that foundation concepts are often not dealt with. For instance, children are expected to learn about the expansion of solids, liquids and gases before they have ever learned about the concepts solid, liquid and gas. Thus, there is little conceptual progression built into the content of one standard, let alone between standards. No links are suggested between the biology and physical science sections and there are no links between the first three years of science and standard 5 science. Clearly there is an implicit view of knowledge as a fragmented, fixed body of immutable facts, to be learned and not understood. Misconceptions are likely to be enforced through the problems outlined.

Whilst it is suggested in the aims that content be applied, there is no provision for this in the syllabus outline. Contextually relevant examples and options might have been included.

Furthermore, the process skills of science are not mentioned and in their absence it must be concluded that the curriculum is content driven.

Thirdly, the status of method within the syllabus needs to be considered. With the exception of the use of observation, particularly of various biological phenomena, very few teaching methods are suggested in the syllabus. This might be interpreted as a mechanism designed to allow teachers to utilise a range of their own methods. However, in reality, the syllabus is a long list of facts, thereby encouraging didactic teaching and rote learning. This is commensurate with the overall positivist view of science implicit in the syllabus. The aims which suggest that pupils be provided with opportunities to do 'independent investigations' (Department of Education 1995b) and opportunities for acquiring skills are not given any status in the bulk of the documentation. Indeed, there is no attempt to promote child-centred learning and it is clear that the relationship between process skills and knowledge generation needs to be considered because any sense of inquiry based science is absent.

Finally, the approaches to assessment recommended in the syllabus need to be discussed. Whilst the previous syllabus made mention of tests at the end of a topic and remedial teaching, the current interim core syllabus gives no consideration to issues of assessment in the standard 2, 3 and 4 syllabus. For the standard 5 syllabus, it is suggested that equal emphasis be given to biology and physical science, further highlighting a false dichotomy between the two subjects. It is also advocated that 'different evaluation techniques should

be applied regularly on a differentiated basis' (Department of Education 1995a), but how this should be interpreted is not clear. Given that most teachers are not familiar with alternative or authentic forms of assessment, it is likely that this will simply mean more frequent testing of students in exam type situations.

Using the conceptual framework (chapter 4, p 77) to analyse the recent process of curriculum development and its products, it is clear that the official curriculum, the syllabus document, is still firmly located within an empirical-analytic paradigm, as was the process of curriculum development by which it was produced. It is also apparent that there was no consideration of lessons from international experience, particularly a move towards more constructivist approaches (chapter 4, p 111).

Furthermore, the curriculum process, as it happened over the last two years, occurred in a way that is not consistent with the broad principles of democracy, nor of those outlined in the Government White Paper (Republic of South Africa, 1995). It is stated in the White Paper that it is 'imperative to undertake an overhaul of the learning programmes in the nation's schools and colleges and 'a fully participatory process of curriculum development and trialling' (p 27) involving all major role players is advocated. It is further suggested that it is necessary to 'set up rapid processes for the production of new curriculum frameworks and core curricula'. However, there are no structures or processes in place to provide an opportunity for those outside of curriculum committees to become engaged in curriculum decision making. For instance, it is this author's experience that of the many

teachers with whom she has interacted, none of them has had access to a copy of the White Paper and many of them have not even heard about it. The State clearly needs to be developing mechanisms to encourage teachers and other educators to engage in policy matters, if it is to move beyond the realm of rhetorical statements. As it stands, these recent curriculum efforts in South Africa are still located within a technocratic approach (Cornbleth, 1990) and are therefore embedded in an empirical-analytic paradigm. This is alarming given London's (1993) view that projects in developing countries fail not so much as a result of 'the implementation of the project but in the plan and the paradigm used' (p 265).

Evidence from the recent past shows that policy around curriculum development remains confused and confusing. For instance, subsequent to the syllabus revision process just described, the Department of Education established 41 national curriculum committees 'as part of the process of taking over from where the NETF had left off' (Department of Education, 1996, appendix 1, p 3). These committees would be responsible for curriculum development in different subjects and for the implementation of the revised syllabuses. This suggests an ongoing view of curriculum development as the manipulation of content within subject disciplines and means that the scope and vision for curriculum change has gone no further than that of the previous administration. This is very disconcerting, especially as the membership of these committees was largely drawn from people who had served on committees of the previous government, and who are therefore likely to have a narrow perspective on curriculum development. Also, those who are new to these



committees may not have had any experience of alternative approaches to curriculum decision making and may become 'locked' into traditional approaches. Without an overarching sets of values and guiding principles to steer the direction of curriculum innovation within these different committees, meaningful and coherent curriculum change is unlikely to take place. Such guiding principles are needed as a basis on which curriculum policy would be formulated and as the framework within which new curriculum practice would happen.

Towards the end of 1995, a Consultative Forum on Curriculum was held in order to develop a curriculum framework for general and further education and training. A discussion document emerged from this process. The document is a significant shift away from traditional content driven curriculum documents as it advocates a holistic framework for curriculum development during the three phases of education. This is driven by a set of principles for learning and teaching that are essentially democratic in nature. The principles that are advocated for curriculum development include the participation of stakeholders in curriculum processes; transparent and accountable processes; and processes that are affordable, sustainable and geared to capacity building. Principles for curriculum design include the learner-centredness; relevance; integration; differentiation and redress; nation-building and non-discrimination; critical and creative thinking and flexibility. The framework provides a basis for the development of lifelong learning in which the outcomes of education are valued over content inputs. Whilst the document represents a significant shift away from a view of knowledge as content and a view of curriculum as the

product of a technical exercise, no mention is made as to how this will be achieved. Proposals relating to structures and processes for curriculum development are notably absent from the document. For instance, no mention is made of the way in which the 41 committees are expected to interact with the document. This is also true of a more recent document that makes proposals about 'Structures for the development of national policy regarding curriculum and related issues' (Department of Education, 1996). Thus, when the National Professional Teachers' Organisation of South Africa (NAPTOSA) queried this issue the response was 'that these (41) committees were to become operational in March 1996 (National Professional Teachers' Organisation of South Africa, 1996, p 7). This suggests that there are two parallel processes operating in South Africa, each driven by its own set of values and located within different paradigms.

Clear statements and mechanisms are needed to redress the imbalance between the policy statements made in government documents, and the practice of curriculum development. Additionally, there is an urgent need to revise the syllabus, so that it begins to reflect the broader needs of society and so that it takes into account international trends in primary science education.

### **5.3 Some trends in curriculum development in developing countries**

The purpose of this section is to outline some of the historical trends in curriculum development in developing countries, drawing especially on experiences in Africa and in

science education. The intention is to outline some of the weaknesses of traditional models of curriculum development, in order to use these experiences to begin to formulate alternatives for South Africa.

Bacchus (1990) identifies three stages in curriculum development in developing contexts. The first phase was prior to colonisation, followed by a middle period in which the colony was established and then a third post independence stage. During the middle stage the trend was to provide education to a few of the indigenous population in order to create a buffer group between the colonialists and the mass of people. He states that the education provided was geared to creating a literate group and also tended to be technical and skills oriented in order to provide labour needed for specific economic endeavours, or to produce clerks, catechists and interpreters (Herget, 1989). When independence was achieved most developing countries aspired to provide an education system similar to that which had been provided by the colonialists, but on a mass scale. Thus, the expansion of education provision has been the major trend subsequent to the independence of many countries.

The introduction of new curricula and curriculum emphases has proved problematic internationally. Kay (1975, p183) noted that the 'majority of curriculum specialists view curriculum planning and design as a technological process' derived from an industrial model where the emphasis is on creating 'standardized means for producing a predetermined result'. She noted that these approaches had been employed in less

developed contexts, like Kenya, and as early as 1975 suggested that a more critical review be undertaken because the traditional curriculum procedures had not produced the anticipated results.

However, in Africa the trend of importing and adopting 'exogenous models of curriculum development' continued on a wide scale (Jansen, 1989) and Lewin (1992) states that this is particularly well noted in the dissemination of science curriculum projects throughout Africa and the developing world generally. For instance, Lewin (1992) notes that the Scottish Integrated Science Programme formed the basis of science programmes in West and Southern Africa, many Caribbean countries and South East Asia. These early curriculum efforts were primarily supported by massive foreign aid donations from developed countries (Yoloye, 1995). Lewin (1992) further notes that changes were restricted to content and that there was little reflection on the nature and purpose of science education. Curriculum development was clearly driven by a research, development and dissemination approach (Havelock, 1971). This is a 'rational' and technical approach to curriculum, development that lays emphasis on product and the outcomes achieved as a result of certain inputs, often material inputs. Thus, Lewin (1992, p15) highlights the fact that 'most attention was focused on the design of written materials for schools', most notably textbooks. Less attention was paid, on the whole, to in-service and pre-service training of teachers and indeed in some cases, such as the ZimSci project in Zimbabwe, the emphasis was on providing a 'teacher-proof technology of instruction, capable of succeeding with limited teacher skill and input' (Hungwe, 1994). This is a deficit view of

education and teacher development (Raubenheimer, 1992/1993) and needs to be guarded against in creating alternative approaches.

An additional issue is that curriculum development initiatives have mostly been at the secondary school level, with few examples of substantial initiatives in primary schooling (Lewin, 1993). This trend is contradictory given that research shows that there are greater social rates of return for investing in primary education (Psacharopoulos and Woodhall, 1985). Hawes and Stephens (1990) point out that by providing more resources to higher education 'we deprive higher education of the very people who we would like to see there: they having fallen by the wayside way back down the line because of *economic* underfunding of primary education' (p 189).

Bajah (1993) says that adoption sometimes occurred without the curriculum developers realising this, and cites the case of how the coordinating secretary of the Nigerian Science teachers' Association had presented teachers with a set of ideas about how to integrate their curriculum. The teachers readily accepted these ideas in the absence of any alternative and thought that this was a radical innovation. It was only when presenting their 'innovation' at an international conference in Scotland a few years later, that one of the developers of the Scottish Integrated Curriculum informed the teachers that their innovation was in fact the Scottish Integrated Curriculum! This example highlights the uncritical acceptance of the ideas of others. Lewin (1993) notes that the straightforward adoption of materials is now quite rare, and that localised curricula are commonly in use.

However, he adds that these have mostly been developed and prescribed centrally by national curriculum development institutes, with little teacher participation. This too is an issue that needs to be reviewed in the context of South Africa.

Developers who promoted their ideas in new contexts must be criticised for their lack of sensitivity as they have not placed any value on local contributions and ideas. The following quotation which refers to a workshop organised by the Harare Generator serves to highlight this point. The workshop was dominated by inputs and organisers from more developed countries, like the UK and USA.

‘One was left wondering whether the workshop organisers assumed that no innovative work had been done in Africa and if that was the case, why they thought there was nothing to be gained from trying to find out the reason for such a situation.’

(African Forum for Childrens’ Literacy in Science and Technology, cited in Bajah, 1993).

This is indicative of a perception that there is little indigenous innovative work and capability in developing countries, and that the developed world needs to ‘show them the way’. In South Africa recognition needs to be given to development work that has been undertaken and capacity that has been built, especially through the work of the non-government organisations. However, it appears that the current government is reticent to engage these organisations in a coherent development plan.

The trend of supplanting innovations has often arisen because the developers have assumed that ideas could be developed centrally and that ‘specific programs or practices

can be validated and transplanted' (St.John, 1991, p 224). In reality this assumption is flawed for many reasons. For instance, such centralised approaches to curriculum development assume that social change is linear and can be engineered in a rational and scientific manner. The many examples of the large scale failure of the technocratic approach show that this is not the case (Gross, *et al*, 1969). It is also assumed that there is consensus about the need for change and that change is itself perceived as desirable and necessary. However, it has usually proved that those for whom change is intended see new innovations as a threat, a nuisance, more work or simply unnecessary. In many instances new ideas have also not taken into consideration vastly different contexts and the ways in which innovations are intended to impact on different settings.

Whilst many initiatives in Africa have focused on materials development and provision, there are a few examples of more innovative work that focused on developing human capacity. One such programme was the African Primary Science Programme (APSP) which later became the Science Education Programme for Africa (SEPA) (Yoloye, 1995). The focus of APSP was 'the child rather than the discipline of science or the society' (Yoloye, 1977, p 135) and a strong orientation to teacher development was chosen. APSP also adopted a cognitive approach to learning by promoting the notion of 'learning how to learn' in different settings (Yoloye, 1977, p135). This is what later became known as a constructivist approach (Putsoa, 1995). At a recent conference of African Science and Technology Education (ASTE, University of Durban-Westville, December 1995) some key questions relating to the APSP experiences were raised. Firstly, it was noted that these

experiences were not well documented by those who were involved. Secondly, it was not clear what legacy these programmes had left behind in Africa. Thirdly, there was uncertainty as to what lessons had been learned from the successes and failures in Africa. There was a call for the commissioning of research to document and analyse the past, for the dissemination of information to current curriculum initiatives and for greater networking between organisation and countries (ASTE, 1996).

It is clear that South Africa has not been the only country in which traditional models of curriculum development have been dominant. The majority of curriculum initiatives in Africa have also been formulated within a traditional approach and are therefore located within an empirical-analytic paradigm. However, Jansen (1989) suggests that in Africa there has been a trend towards critical modes of curriculum. He ascribes this trend to the difficulties associated with implementing imported approaches at the local level, to the critique of the dominance of Western norms and values, and to the acceptance of socialist principles by many governments after independence. Whilst this may be true, case studies and examples of curriculum initiatives that adopt a more socially relevant stance are still limited and in general it can be stated that little attention has been given to such alternatives. For instance, at the recent ASTE conference only a limited number of case studies cited more exciting examples of curriculum innovation (Savage, 1995).

There is a need for alternative approaches to curriculum development that move away from an empirical-analytic paradigm. This means a closer examination of cases which do



take into account the variety of contexts in which innovations are meant to work. Lewin and Stuart (1991) capture a number of case studies under four main focus areas, namely curriculum reform within a subject area; innovations to support change amongst teachers; the institutional contexts of change; and innovation at the whole system level.

The purpose of the next section is similarly to review some innovative case studies from developing countries, including from South Africa, and then to examine some of the issues which need consideration in curriculum reconstruction in South Africa. Along the lines of Lewin and Stuart, these will be categorised into five key areas, namely selection of appropriate content; materials development; teacher participation; inservice education of teachers; and systemic change. A set of key messages, derived from international experience and from lessons from such alternatives are proposed. The intention is not to locate the key messages within a particular paradigm, but to highlight some important lessons which can contribute to the development of a new paradigm for science education and curriculum development in South Africa, based on alternative approaches and methods used in successful cases. It was argued in chapter two that new paradigms for curriculum inquiry (p 12) and for science education (p 48) are needed. The assumption here is that paradigm mediation (pp 46, 65, 70 and 92) is possible for the creation of this new paradigm.

#### **5.4 Selection of appropriate content**

Prior to the selection of content for a curriculum, it is necessary to define the aims and purposes of science education. However, this activity in itself might not be sufficient if the aims and purposes are not translated into the content selected. If this is not done then there is likely to be a mismatch between the aims and what is actually done in classrooms. For example, Sawyerr (1985) notes that children in Sierra Leone were not taught to apply scientific knowledge, nor to solve problems using science, and were not prepared for the world of work. This is despite the fact that these were goals elaborated for the science curriculum. Clearly greater attention needs to be given to examining the purposes of science education as experience has shown that science, of itself, has not produced the desired economic goals, nor the goals of scientific literacy (Garrett, 1990). This is despite the fact that great faith has been put in science to promote industrialisation, economic growth and technological advancement (Hungwe, 1994). Kahn (1991), who was working in Botswana, suggested that the role of science and technology education needs to be linked to the development of a holistic framework for development within a given country.

In South Africa a group of people working under the auspices of the Centre for Education and Policy Development (CEPD) attempted to redefine a set of aims for science and technology in South Africa (CEPD, 1995) and to translate these aims into content areas. The aims attempt to delineate the relationship between science, technology and the broader society; and the learner's potential role within this. A broader set of skills, related

to the learner's future place in society, are also promoted. These are consistent with the call for a more socially relevant curriculum which lays emphasis on science, technology and society; as was elaborated more fully in chapter four (p 109). The group also advocated that children should start learning science from the first year of school so that basic scientific and technological literacy can be developed in these first years, as this is the only science education that some children might receive. Many of the proposals outlined in the CEPD document were based on the work of the Science Curriculum Initiative in South Africa (SCISA) (see for example McNaught, Raubenheimer and Keogh, 1989; SCISA, 1992) and are informed by developments in science education in other parts of the world, some of which have been outlined in the previous two chapters.

However, the CEPD group did not consider the role of science and technology education within the broader context of development. Concern for this broader role for science and technology has been taken up by those who are focusing on the broader aspects of Science & Technology (S & T) policy. In 1993 the International Research and Development Centre (IDRC) in South Africa conducted a review of S & T policy in the country. They defined S & T policy as being 'concerned with the generation, acquisition and application of knowledge from the sciences' (IDRC, 1993, p 7). The focus of their survey was on the tertiary, industrial, agricultural, environmental and research sectors, but there was no mention of the relationship of S & T to education. Similarly, the recent draft green paper on Science and Technology (The Department of Arts, Culture, Science and Technology, 1996) only discusses the relationship of S & T to the 'higher education sector' (p 69), by

which is meant tertiary institutions. There is no discussion of the relationship of S & T to schooling. When promoters of the document were challenged on this issue at a recent presentation to interested parties at the University of Durban-Westville, it was stated that this should be the brief of the Ministry of Education. An opportunity for elaborating this relationship within the broader context of development has been missed. Submissions to this effect are urgently needed so that S & T can be seen in its broader context.

The constructivist approaches to teaching and learning outlined in chapters four (pp 95, 103) emphasise the need to find out children's existing ideas and experiences as the basis for further learning and for curriculum development. Jegede (1995) argues that science education in Africa tends to promote only one worldview, that of western science, and that little consideration is given to traditional knowledge constructs. This means that children often develop a duality of worldviews that causes 'a kind of ethnic schizophrenia' (Jegede, 1995, p 13) because the two forms of knowledge run alongside each other. This has been made more serious by the traditional models of curriculum transfer from the west to Africa which ignored local contexts (Tobin, 1994). Thus, Ogunniyi (1995) warns that western science should not be perceived as the 'correct' worldview, as this would denigrate traditional forms of knowledge and scientific traditions. Instead, curriculum and materials development programmes must use the African worldview, indigenous technologies and the practice of indigenous science as the foundation for development (Herget, 1989). He also advocates that comparative philosophy be taught to teachers

during pre-service education so that they can examine alternative epistemological and philosophical frameworks for teaching science.

Urevbu (1984) examined Nigerian childrens' concepts of energy at different school levels and suggested that the information be used to 'match curriculum with thinking strategies of children' (p 255). However, in most developing countries there is inadequate information on the ways in which 'children learn science and the conceptual and cultural problems they encounter' (Lewin, 1993, p 9). Such baseline studies are needed for curriculum development purposes in most developing countries, including South Africa. It is insufficient for curriculum developers to rely on information from other contexts. Additionally, information on teaching approaches that enhance conceptual formation are urgently needed at the primary level.

In order to overcome some of these tensions and general lack of information, it may be necessary to adopt a compromise. Peacock (1994a) analysed the content of curricula from several countries around the world and found that there is a common core of content that tends to be covered. He suggests that this become the 'minimum entitlement' (p 4) for all children in developed and developing contexts where the focus is on developing core concepts and skills. Contextual sensitivity would still be possible. He adds that the common core be supplemented by a 'locally adapted' science programme that has 'specific local relevance in respect of the economic and productive environment in which children live' (p 4). These local options would be generated in discussion with local teachers,

parents and other key persons in the community. He cites an example from Ethiopia in which topics such as ‘clean drinking water; planting fodder crops; and irrigation development’ are included as local options. These topics are focused on the needs of particular communities and provide children with necessary life skills and a deeper understanding of the environment in which they live.

A similar approach was advocated by the CEPD working group who suggested a move away from straight content topics, towards the development of themes, which would cover a range of key and core concepts. Their intention was not to develop a syllabus, but to provide a framework within which curriculum development could occur. However, they did provide examples of themes and what might be included in them for the three stages of compulsory schooling. One example was the theme of ‘housing’. At stage 1 of education (years 0 - 3) the focus might be on children playing with different textures of materials, building their own basic structures, developing the notion of shape and boundary. At stage 2 (years 4 - 6) the properties of materials might be more fully investigated, as could measurement, and issues relating to household waste and recycling. At stage 3 (years 7 - 9) more sophisticated measurements of area and volume might be undertaken, energy transfer within different kinds of structures might be considered, and a further analysis of materials might be undertaken in terms of their properties and the physical and chemical transformations they have gone through. It is clear that this theme develops several core concepts, like texture, measurement and scale, shape, energy transfer, humans as part of the ecosystem, and so forth. Thus, concepts are integrated into the content of themes and are not dealt in isolation from real world situations. The CEPD proposals are clearly

underpinning the proposals and these are essentially constructivist in nature. The need to develop pupils' skills is also recognised and the distinction is made between two forms of skills; namely skills for generating and testing ideas, and skills for handling and communicating information. This means that the proposals adopted a concept/process based approach to science.

In the CEPD document reference is also made to the three stages of general education for South Africa and this is linked to the anticipated conceptual abilities and the expected level of pupils' skills. It is acknowledged that the curriculum in each of the three phases must take into account pupils' existing abilities, concepts and experiences as the basis for development. Similarly, the recent 'Curriculum framework for general and further education and training' (Department of National Education, 1995c) also recognises the different abilities and needs of children in the different phases of education. This approach is consistent with international experience which shows that childrens' conceptual knowledge and abilities progress over time and are often age related.

At this stage it is not certain what is going to happen to the CEPD proposals and the decision in this regard still appears to lie within the subject committee for science. Presently, there are some individuals, like Gray (ASTE Communique, 1996), and organisations like the Institute for Partnerships between Education and Business (IPEB) (Raubenheimer, 1996) and SCISA (SCISA, 1996) who are currently trying to develop exemplar classroom materials which adopt some of the approaches advocated by the

CEPD. These might be used to lobby for small scale, incremental changes in the syllabus, because one of the major difficulties which curriculum developers will have to tackle is how to introduce fundamental changes to the curriculum. It is unlikely that the entire syllabus will be rewritten within one syllabus revision cycle because this has major implications with respect to the provision of resources and materials, and on the retraining of teachers.

There are several other aspects that need consideration when selecting content, including an exploration of gender issues (Rollnick and Reddy, 1995), examining prejudices relating to race (Shah, 1994) and the imbalances between urban and rural contexts. The role of language in conceptual development, and the medium of instruction for science (Brookes and Brookes, 1995, Bhendane, 1996) are also key issues which need to be considered in the context of South Africa. The latter issues are large areas for investigation and are therefore beyond the scope of this study.

**Key messages are that curriculum content must take account of childrens' existing abilities and their prior experiences of local conditions, values and norms; and consider the broader purposes of science education in society. Pupil's learning in science must be motivated by their own interest and enthusiasm and by real action oriented projects so as to provide an understanding of the broader issues in society (chapter 4, p 110). Curricula must be constructed that take account of children's domains of experience at different ages and these need to be sequenced over the**



years of science education (chapter 4, p 103). Additionally, a concept/process based approach is advocated (chapter 4, 106) in which process and thinking skills are used as a means to construct conceptual frameworks and linkages between concepts. The role of language in conceptual development needs to be given more careful consideration (chapter 4, p 96). These suggestions are consistent with the international trend towards a constructivist approach to teaching and learning (chapter 4, pp 106, 110).

### **5.5 Materials development and resourcing the curriculum**

Fabiano (1995) delineates five areas for resourcing the curriculum, namely quality and quantity of teachers; printed teaching and learning materials; laboratory space, equipment and consumable materials; school environment; and financial resources. Whilst all of these aspects are interrelated, issues relating to teacher quality and quantity will be dealt with in a subsequent section. Thus, the focus of this section is primarily on material resources and the curriculum.

Lewin (1993) found that in developing countries there has been a belief that the provision of materials would be sufficient to bring about change in educational practice. He dismisses this myth by making it clear that the desired effects have not been achieved.

Despite this, Fuller and Clarke (1993, cited in Moulton, 1994) found a positive correlation between the provision of textbooks and student achievement. This work was based on earlier work by Fuller (1987) in which he reviews the literature in developing contexts and analyses which factors raise school achievement. Certain variables in the school context (like availability of textbooks, libraries, pupil numbers, teacher qualifications) were decided upon and their relationship to school and pupil performance (as determined by exam results) established using multivariate analysis. This is commonly known as the education production-function model as it explores the relationship between inputs and outputs (production) in education. The purpose of such studies is to identify factors that contribute to enhanced education quality, and particularly the cost effectiveness of certain inputs (Lockheed and Verspoor, 1991), and are based on the assumption that variables can be controlled in order to establish which variables are the most economically viable. The studies assume a universality of values, concepts and perceptions and assume that what is found in one country will apply to another. This is based on a scientific approach to research and is clearly embedded in a traditional paradigm.

Chinapah (1983, cited in Chinapah and Miron, 1990, p 43) is critical of this view stating that schools are considered as 'firms, industries or production units designed to maximise the scholastic performance of children' and suggests that this should not be the aim of education. Similarly, Moulton (1994) notes that whilst Fuller and Clarke (1993, cited in Moulton, 1994) looked at both availability and use of textbooks, it is not clear what these terms mean, nor how the researchers established what effective use is. Moulton (1994)

adds that the 'researchers apparently assumed that if books were present, they were being used effectively' (p 6). She further questions their research by conducting a qualitative analysis of the same studies surveyed by Fuller and Clarke and she raises some key issues for consideration. She notes that in some studies, 'any indication that materials were actually used was lacking (p 6)', that teachers tended to use textbooks themselves but did not make them available to pupils, and that completely different results were obtained between two countries that had similar resources. She is particularly critical that the researchers did not utilise classroom based observations or interviews with teachers to substantiate their claims and to find out what teachers actually do in classrooms. Thus, she has raised considerable doubt as to the validity and value of these multivariate studies. Whilst such studies are cost effective and might provide indications of broad trends, there is insufficient insight given to establish the meaning of the data in particular contexts.

Moulton (1994) continues her study by examining three case studies (Chile, Botswana and Ghana) in which teachers were observed using materials in their classrooms. She notes that there are conflicts between the ways in which teachers say they use materials and what they actually do in their classes - that 'teachers tend to exaggerate their use of textbooks when asked on questionnaires' (p 10). The Ghana study showed that teachers used textbooks in a number of ways, like copying chunks of text onto the board for pupils to copy or recite, or copying exercises from the textbook onto the board for pupils to copy into their exercise books - instead of directing pupils to work from their own textbooks. In only one school were children given textbooks for independent reading.

Moulton (1994) concludes that much more information is needed in 'all countries, including South Africa' as to (i) the extent to which teachers use text material, (ii) the ways in which different teachers use such material, and (iii) the effects that their use has on pupils. Such baseline research is needed in order to develop materials that meet teachers' needs, and to develop programmes to familiarise teachers with alternative approaches to using text materials.

Lapp (1995b) takes issue with the view, advocated by Savage (1995), that materials do not bring about change, and says that good teachers can make effective use of well designed materials and indeed need material support. What seems to be at issue here is not so much whether materials embody change, but whether teachers are able to make effective use of materials and what conditions are necessary to facilitate this.

In South Africa, the Handspring Trust for Puppetry in Education (1994) conducted an evaluation to determine the ways in which teachers used a multi-media package of materials, called Spider's Place, that included a video, a comic and a pupils' worksheet. This evaluation also showed that teachers use materials in many different ways, but that the most common way was to give pupils the comic to read in their own time, as supplementary material to reinforce or revise content. Teachers found it difficult to integrate the comic into their everyday teaching as this was a complex task. The video and worksheet were less commonly used. The conclusions drawn from the findings were that teachers need 'intensive orientation in the use of new materials' (p 41) because 'teachers

need to understand the goals of the innovation, the approach to science teaching and learning as well as the conception of science and scientific knowledge embedded in the materials'. These findings support the recommendations made by Moulton (1994), that more information is needed in order for materials developers to meet the needs of teachers.

In South Africa, MacDonald (1990) and van Rooyen (1990) showed that pupils who move from mother-tongue instruction in standard two to instruction in English in standard three do not have the requisite vocabulary to cope with the new scientific knowledge being presented to them. Similarly, van Rooyen (1990) conducted a readability study of primary school textbooks and found that books were poorly written for the linguistic level of pupils. There was 'a possible incomprehension to 60% of the sentences' (p 98) in one text and a minimum incomprehension level of 27% in other texts surveyed. This means that it is unlikely that pupils will be able to deduce any coherent meaning from the textbooks in use. These are also crucial aspects for consideration in the development of new text material in South Africa.

The role of teachers in materials development has received little attention in South Africa. Typically, materials are developed for teachers. Peacock (1994b), referring to the development of the Spider's Place materials, suggested that the materials development be seen as 'separate from the process of teacher development' (p 6) because teachers lack the skills and time for such activities, especially when materials are complex and sophisticated.

In such instances, the relationship between development and piloting and testing in classrooms needs to be clarified.

That teachers can be productively involved in materials development has been shown by SCISA (SCISA, 1994) and the Primary Science Programme (Raubenheimer, 1993). SCISA has established a number of writers' circles comprised of groups of teachers working on a particular topic of the syllabus and has shown that teachers can produce good quality classroom material. However, the experiences of SCISA show that teachers need external support for such projects, including technical expertise and ongoing motivational support. Raubenheimer (1993) documents the experience of involving primary science teachers and inservice educators in a dialectic relationship to produce materials. The inservice educators provided a framework for materials development and theoretical inputs relating to current trends in science education, whilst the teachers generated practical classroom ideas relating to what is possible in 'real' primary school classes. The inservice educators then modified materials and sent them back to teachers for further piloting and testing. This was an attempt to develop an ongoing and dialectic relationship between the centre and the periphery. However, problems were encountered, especially related to substantive trialing of materials in classes because of insufficient staff and time to work alongside teachers in testing materials. Despite the problems, both projects have highlighted that teachers can make a valuable contribution to developing materials and that these materials are used in the classrooms of teachers who were involved in the projects. Unfortunately, the findings of these two initiatives have not been

widely disseminated, but these projects urgently need to be documented and lobbied as examples of alternative practice that could be taken up by education officials. Project staff are currently working on this issue.

Curriculum development and materials development were historically seen as synonymous processes. **Key messages are that materials in and of themselves do not embody the capacity for change, and that attempts to bring about curriculum change through the provision of materials have largely been unsuccessful. However, teachers do need material resources to make their teaching more effective and commitment to using such materials increases when they are actively involved in developmental processes. Such materials should build on existing research about how children learn (chapter 4, p 102 should adopt a conceptual change approach and should develop connectedness amongst concepts and build schema (chapter 4, p 103).**

Clearly, there are many questions which still need to be researched in order to undertake more meaningful processes of materials development and to develop materials that will enhance the teaching and learning process.

## **5.6 Teacher participation in curriculum development**

Bayona, Carter and Punch (1990) note that there are contesting views about whether teachers should have a role in curriculum development. They add that teacher participation

is not common in developing countries, primarily because curriculum development is a centralised process. They then give a coherent argument, which is supported by theoretical points and a literature survey, as to why teachers need to be party to curriculum decision making processes. Key points highlighted include the argument that all teachers are curriculum developers because they make ongoing and autonomous decisions about what happens in their classrooms, whether this a conscious or subconscious process. Such decisions are often based on knowledge of local context and knowledge of their students' abilities. The authors further suggest that centre-periphery models of curriculum, as they are commonly practiced, tend to alienate teachers because 'there are frequent conflicts between the demands of externally developed curricula and the teacher's classroom context' (p 17). They also record some of the objections to involving teachers in curriculum development, such as, that teachers do not have the knowledge and skills to engage in curriculum development; or that teachers do not have the time to perform these tasks; or that there are resource and financial implications for teacher involvement. They then state that these issues can be addressed and should not be used to prevent teacher participation.

Punch and Bayona (1990), drawing on their previous work, advocate a model for teacher participation in curriculum development in Tanzania, where a highly centralised model of curriculum development has dominated. Their model suggests a five tiered system with teachers represented at every level and attempts to find ways to work more effectively within an existing hierarchical system. A set of key principles to provide the framework



within which curriculum policy should be formulated, are advocated. They suggest that once a model is established it is necessary to gain support for it at all levels in the system and to ensure that there is commitment to the more participatory process. This would include creating new legislation to enact the new model. However, they do not state whether this model has been tried in practice.

Garrett (1990) suggests a model for developing countries in which teachers are initially asked to develop 10% of the curriculum, including the selection of aims, content, methods and assessment techniques. He suggested that this be made compulsory for all teachers and that it be linked to extrinsic motivating factors in the form of accreditation, promotion and the identification of teacher leaders. Inspectors would be expected to assume the role of assessing teacher materials and performance. There are some problems with the model, which if overcome, would make it worthy of consideration. Firstly, if teachers are not provided with any additional resources and skills prior to being expected to produce materials, they might feel threatened by the process. Also, a sense of inferiority could be reinforced in those teachers not able to perform the new role. Some form of initial inservice training of teachers would be a prerequisite. Secondly, extrinsic motivators can be open to abuse. For instance, inspectors themselves may not have the knowledge and skills to evaluate teacher efforts and might recommend inappropriate promotions. They too would need to undergo some education. To prevent evaluation being subjective to one person and to curb any misuse of the system, some safety mechanisms would need to be put in place.

Gilbert (1995) advocated the use of action research in South Africa as a large scale strategy to bring about curriculum reform, because this has proved so successful in New Zealand. However, Gilbert (1995) failed to relate his experiences to the South African context and assumes a level of development amongst teachers that is not the case. Because of this it is unlikely that action research could be introduced in any sustained way as a major approach to curriculum renewal. Russell (1993) also recommends the use of action research as a means of developing small-scale, local action research projects in developing countries and then suggests these be used as the basis for further development at regional and national levels. Whilst his suggestions are more feasible in the context of South Africa, it will however, still lead to the exclusion of many teachers who do not have action research skills. He also suggests that teachers be supported by 'curriculum developers, tertiary institutions and NGO staff or other appropriate personnel' (p13), but in the context of South Africa, there is still an insufficient understanding of action research and capacity to make this fully viable. Projects are needed to develop this research capacity.

In South Africa teacher participation in curriculum decision making has been very limited. Mostly, it has been restricted to the involvement of a few nominated teachers in subject committees. This is inadequate as teachers are not representatively elected and so there are no mechanisms for reporting back to the broader group of teachers on decisions made. Also, only a limited number of teachers have developed any skills in curriculum development, further contributing to the perception that teachers cannot participate in

curriculum decision making. This produces a cycle of non-participation - that is, teachers are not involved in decision making and are never given the opportunity to develop the skills and confidence needed, and so even when asked to become involved they feel that it is not their duty or right.

Several of the non-governmental organisations (NGOs) in South Africa have tried to engage teachers in decision making processes in order to empower teachers within their particular contexts. Raubenheimer (1992/93) notes that this is often a threatening process for the teacher as s/he must challenge her/his own assumptions about teaching and learning, as well as interacting with others in a highly authoritarian system in order to bring about change. Thus, whilst teachers may participate in decision making regarding the INSET organisation concerned, they are often not able to make the same level of contribution in their schools because the power structures and organisational values mitigate against this (Raubenheimer, 1992/93). Furthermore, Ndimande (1996) notes that the policy rhetoric of at least one major non-governmental inservice education provider does not marry with practice. He highlights that teacher participation is restricted to the choice of topics for a subsequent workshop, and that no meaningful participation in key decision making takes place. So, even though some NGOs have espoused democratic principles, they have not fully implemented these ideas. This may be a consequence of the dominant paradigm in the country that favours autocratic and authoritarian attitudes, such that these are so embedded in our own actions that it is extremely difficult to break away from them.

It has already been stated in section 5.2 (p 121) that teachers are not familiar with current policy recommendations and are alienated from the policy making process. It is also clear that structural mechanisms and support processes, possibly along the lines of those suggested by Punch and Bayona (1990) or Garrett (1990), are needed to ensure greater teacher involvement, in addition to the political will to enact the policy recommendations of the White Paper. The CEPD science and technology proposals (CEPD, 1995) also make recommendations as to how greater teacher participation could be promoted by education departments in South Africa. Policy is urgently needed on the role that teachers should play at different levels of decision making within the system, that is, at classroom, school, local, regional and national levels. Such policy should be generated in consultation with teachers. Thus, pressure groups, like teacher unions, need to lobby for greater teacher participation in generating curriculum and policy matters.

**Key messages are that teachers have a role to play in curriculum development and should actively be engaged in these processes in order to develop skills needed to become curriculum developers at various levels. Active involvement in development processes at various levels leads to a greater commitment to and understanding of change. There is the need to consider the role of teachers at several levels in the system in the attempt to make central and local processes compatible. Support structures are a necessary component for teachers to be curriculum developers at any level (chapter 4, p 101)**

## **5.7 Inservice education of teachers**

Holbrook (1991) states that within project 2000+, which is aimed at regenerating science education internationally, the 'biggest obstacle to future progress is in the persuasion of teachers to accept and implement the changes being proposed' (p 4) and adds that 'many science specialist teachers need to change their outlook, philosophy and practice' and that they should be persuaded to do this. Whilst change is indeed necessary, the lessons from historical attempts at curriculum development show that persuasion, by centralised curriculum agencies and governments, have produced very little change. Inservice education and training of teachers (INSET) may be one way in which to introduce teachers to new innovations and to bring about such changes. It has already been noted that inservice education has not been a major focus of development work in developing contexts (Lewin, 1993), excepting in the case of APSP and SEPA (Yoloye, 1977).

In South Africa inservice education has been provided by both state and non-governmental organisations although the latter have been the major providers of inservice education (Bot, 1986). Inservice education has led to accreditation in some cases, but has largely been non-formal. McNaught and Raubenheimer (1991) noted a fundamental difference between the INSET provided by the state and that provided by non-governmental organisations. State provided INSET tended to adopt the view that 'all that teachers need is more of the same' (p 7), or that a 'quick fix' would overcome the problems and that this

could be provided in courses which were content oriented and typically lasted for one week. The approach was highly technicist, with much of the training being done by means of computers and videos, and with little classroom focus. In contrast, INSET provided by non-governmental organisations tended to be more long term and school focused.

Harvey (1994) examined a broad spectrum of teacher's scientific concepts in one area of KwaZulu Natal prior to INSET courses. He used a questionnaire to assess teacher's existing conceptions of particular phenomena. Harvey (1994) notes that teachers hold many alternative conceptions and misconceptions about primary science content. He used the information he gathered in order to design activities that challenge teachers' existing notions in an attempt to address their conceptual difficulties. Clearly, there is a need for preservice and inservice education that addresses this issue on a broader scale. This is also an issue raised internationally, that is to address teacher's conceptual knowledge, so that they do not teach wrong concepts to children (chapter 4, p 100).

Whilst it is acknowledge that most inservice activities in South Africa are school focused, these have tended to occur away from the teachers' classrooms (Hofmeyr, 1994), and so it has been found that teachers have difficulty in transferring new learnings to their own classroom situation (McNaught and Raubenheimer, 1991; Peacock, 1994). For instance, Peacock (1994) notes that many teachers called themselves constructivists, and referred to group work being done by pupils as an example of a constructivist approach they were using. However, whilst children were sitting in groups, there was little change in the

patterns of interaction between the teacher and pupils. Lessons were still strongly teacher centred, with teachers talking to individuals in groups, and with little interaction occurring between pupils in a group. This is consistent with international trends which highlight the difficulties in bringing about classroom change. Some INSET providers, such as the Primary Science Programme, have recognised the need to involve children in teacher INSET, so that teachers get the opportunity to develop and practice new methods within the safe confines of the INSET providers, and with pupils who are not their own students (Raubenheimer, 1995b). Thus, teachers feel free to experiment and make mistakes in open and reflective forums. However, these approaches are not widespread and in general clearly articulated models of primary science INSET are absent in South Africa. More research and documentation in this area are urgently needed in order to promote more appropriate models of curriculum and teacher development.

Additionally, classroom follow-up and support mechanisms are a crucial component of inservice education (Raubenheimer, 1995c, Harvey, 1996). Many NGO providers have undertaken classroom support but these have often focused on monitoring whether teachers have implemented according to the predetermined requirements of the NGO, and such approaches appear to be located in a traditional paradigm. An alternative approach was adopted by Harvey (1996) who has worked alongside teachers in co-planning, co-presenting and co-reflecting on lessons they taught. Shared criteria for observation were firstly negotiated with all teachers at focus schools, and these formed the basis of the reflective observation sessions. Other INSET workers have opted for action research

techniques (Mhlongo and Hlatswayo, 1995; Chabane, 1993) as viable approaches for supporting teachers to become reflective of their own interactions with pupils and as a way to engage with their successes and failures. The development of shared criteria, as advocated by Harvey (1996), seems to be a viable model that could be adopted within broader education circles, for example by inspectors and subject advisors. This approach does not rely on the open ended nature of action research, but is instead a more formalised, but negotiated approach, to classroom observation. Those embedded in a more traditional approach to teacher appraisal could quite easily engage with this process.

Typically, most INSET has been content oriented with some attention being paid to teaching methodology. Goodwin and Taylor (1992) describe their work with primary science teachers in Kenya and conclude that ‘effective progress lies much more in the process which is engaged rather than the solution provided’ (p 14). This is a similar message to that promoted by Raubenheimer (1992/93) where she states that INSET must operate within a competency model, in which teachers’ existing abilities are given status, and that INSET must be geared to empowering teachers to take ownership over their own actions. Increased self-confidence and competence are then likely to be outcomes of INSET. Goodwin and Taylor (1992) note that participants were also more ready to ‘identify problems, seek appropriate knowledge and to invent and evaluate solutions’ (p 14). These are important goals for inservice education.



Greenland (1983) identified four major purposes of inservice education:- qualifying the underqualified teacher; upgrading underqualified and qualified teachers; education for new roles; and curriculum related inservice education. In South Africa the focus has been on the upgrading of teacher's qualifications and abilities. However, there also needs to be INSET to prepare teachers to meet new roles, like becoming curriculum developers or head teachers, or for advisors to become active change agents and supporters of innovation. The geographical spread over which most NGOs have operated has been limited due to financial and human resource constraints. Even those INSET providers that operate nationally are not able to provide inservice education to all teachers, and this is compounded by the need for monitoring and classroom based work. Thus, the retraining of advisors and inspectors to perform new roles is crucial and several NGOs are preparing themselves to perform this function for the government. However, there may be a perception by education departments that they do not need the expertise of the NGOs or that NGOs are more trouble than they are worth because they are not accountable to the department. The latter point was made to the author by two senior education officials. Whatever the cause, most education departments appear to be dragging their heels on this issue. NGO coalitions are needed to pressure for closer relationships, although it must be recognised that, in essence, NGOs hold no power over this decision. It would be unfortunate if this role did not fall to the NGOs as staff in government departments have neither the experience nor the expertise in the development, training and management of innovation.

The African National Congress (ANC) draft policy framework for education and training (ANC, 1994, p 52) suggests that inservice education be linked to the concept of ‘whole school review’, but this concept has not yet been adequately conceptualised or considered within education policy debates. For instance, this was not taken forward in the White Paper (Republic of South Africa, 1995), although the inservice education of teachers was seen as a crucial component of developing teacher capacity. In South Africa more coherent research is urgently needed in the sphere of school based inservice education, as it is recognised internationally that the most effective form of inservice education of teachers is school based and part of whole school development (Hopkins, 1995). Greater consideration also needs to be given to the models of inquiry based inservice education that have proved successful in other contexts (ASTE, 1996), such as those adopting a conceptual change model and outlined in chapter 4 (p 100, 101).

**Key messages are that INSET has an important role to play in developing new approaches to the teaching and learning of science, and in preparing teachers for new roles in curriculum decision making. Approaches to INSET must make provision for dealing with real classroom issues and model approaches that can lead to teacher empowerment (chapter 4, p 101). Support mechanisms are also a crucial component for bringing about classroom change. Teachers’ existing conceptual frameworks also need to be used as the basis for INSET activities (chapter 4, p 100, 101).**

## **5.8 Models of systemic change**

Despite widescale efforts to reform education internationally, very little has changed in the majority of classrooms (St.John, 1991) and Jansen (1994, p 6) adds that ‘the single most important lesson from decades of curriculum implementation studies is that policy intentions seldom define classroom practice irrespective of the resources available’. St. John (1991) also suggests that there are two main reasons for this, namely the scale and inertia of the education system; and that the basic metaphor of change is flawed, that is the project-centred infusion or catalyzing metaphor of change. These are important lessons for South Africa. It is necessary to develop alternative metaphors for change and to find ways to overcome the inertia of the system. The intention of this section is not to review the literature on change, but to explore some examples of innovations that have produced change and to highlight some additional key messages.

Warwick (1982) describes three main approaches to the implementation of innovations in developing contexts, namely the machine model, the games model and the evolutionary model. He is particularly critical of the machine model as it is assumed that a clearly formulated plan, backed by ‘hierarchical authority, trained staff, and close supervision’ (p 179) are the only essential ingredients for successful implementation. As an alternative to this approach he recommends ‘implementation as transaction’ (p 180) in which those affected by the innovation are integrally involved. This includes negotiation amongst

parties with conflicting or diverging interests and a conscious consideration of the context of implementation in order to develop an appropriate plan of action.

**Key elements are therefore, stakeholder participation, negotiation, and a consideration of local environmental and political factors. Also, 'All real change involves loss, anxiety and struggle' (Fullan, 1990, p 31) and therefore requires strong commitment from those involved in the process.** Whilst these are key elements for change, they must be considered within the context of bureaucratic and autocratic systems.

Atkin (1994) advocates another metaphor of change and suggests that innovative projects should firstly work with teachers who are already predisposed to thinking critically about their work and who are geared towards change. He notes that recent reform efforts in California adopted this approach and worked with approximately 20% of the teaching population. This proportion of teachers readily understood new ideas and innovations and were 'continually and systematically searching for new and more effective ways of serving their students' (p 5) and so were willing to experiment with and create new approaches that work in their contexts. Once these teachers were committed to change, they in turn began to influence an additional 15 to 20% of teachers through teacher networks, bringing the total number of teachers committed to change to 35 to 40%. He suggests that once this critical mass has been reached, there is a rapid transition to accepting new ideas by the remaining group of teachers. This model, however, requires good communication

channels, established teacher networks and support structures. These conditions for change are not always present in the educational system in South Africa and need to be further developed. The work of the NGOs has gone a long way to developing the infrastructure of teacher committees and subject groupings, but these now need to be recognised and supported by the education departments. Recognition should not just be on paper, but through an active effort to consult and draw on the expertise of teachers.

**The key message in Atkin's words is that 'there is no substitute for groups of teachers who share similar goals and who work in comparable settings getting together to share ideas, problems, frustrations and successes' (Atkin, 1994, p 4).**

The model proposed by Atkin (1994) is reminiscent of the social interaction model of curriculum development described by Havelock (1971). In this model, change is slow at first, but gradually gains momentum and can be traced like a sigmoid curve. Within this model, the important consideration is that individuals become 'actors', discussing and promoting new ideas, which they believe in and can validate with significant others - often their peers. Savage (1995) says 'it is widely acknowledged that, ultimately it is the teachers who sustain classroom change' (p 10) and cites examples of exceptional teachers working under arduous conditions. Hawes and Stephens (1990) also see teachers as the main agents of change and note four necessary conditions for the empowerment of teachers. These are knowledge, trust, co-operation and accountability. However, it must be recognised that teachers are at the bottom of the pile in terms of power and control of education decision making and need support to break through many of these blocks. One

way to achieve this might be through upgrading courses, like further diplomas of education offered at colleges of education and universities, in which teachers are taught new theories and methods. Teachers could be encouraged, as part of their course requirements, to establish teacher support groups, and to conduct classroom based workshops with other teachers. The course providers would need to seek the necessary permission for this approach from the education authorities. Groups have more power than individuals and in this way some power blocks might be challenged, and new ideas promoted to a broader range of teachers. A core of competent professionals, with skills of negotiation and organisation, and able to engage in policy debates and theoretical issues, would be actively established. Such teachers could help overcome the inertia of the system by providing a powerful voice for change in science education. **The key message is that individuals can become agents of change, but usually need support mechanisms to help them overcome power relationships that are resistant to change.**

There are few observational studies of classrooms in developing countries (Fuller, 1987). Lewin (1993) cites four examples of such studies in science education and draws the conclusion that these studies show how ‘difficult it is to change established traditions of teaching and learning’ (p 8). This further highlights the need for more in depth studies of particular issues in which contextual factors are given greater consideration. For instance, case studies which describe the conditions under which teachers have changed their practice are needed. Such information would contribute to the design and planning of curriculum development and inservice education programmes. Without more detailed

information of this nature, the 'planner's paradox' (p 9) which Lewin (1993) identifies will remain. This paradox relates to the intentions of planners who wish to bring about improvements in education, but because of the intrusiveness of innovations, actually diminish results. The best way to reduce the paradox is to involve those for whom any innovation is intended (Lewin, 1994). Furthermore, where examples of good practice exist, these need to be communicated to other teachers and to those in the system hierarchy. It is a truism that research findings generally remain locked within the confines of academic institutions and academic journals and are not communicated to the broader audience who should be receiving such messages. Thus, we preach to the already converted. A journal for teachers, circulated by the education department to all schools, might be one mechanism to facilitate this. This might help overcome individual or local inertia. **The key message is that reform efforts must be grounded in the realities of the classroom (Lapp, 1995b) by considering the constraints within which teachers work, if they are to be effective.**

Lange (1995), working in Tanzania, advocates another model of systemic change. He was one of the founders of the Tanzanian science camps in which children are brought into a centre for a period of 2 to 3 weeks for intensive periods of interaction with science activities. At the recent African Science and Technology Educators conference the Zanzibar Science Camp Project was acclaimed as 'an extraordinary model of school change' (Savage, 1995, p6). Lange (1995) notes several principles and characteristics that make the project viable. Firstly, children are central to the learning process and so a key

aspect revolved around finding out about the ways in which children learn and interact with adults in settings outside of the formal school system. This allows for the freedom of interaction and experimentation in an open setting, but the learnings can subsequently be translated into classroom practice. Another key component was that the people who ran the camp are representative of the entire education system - 'all levels of the hierarchy are visibly involved in the project' (p 131). In this way, the project developed alongside the system and so the necessary support for and ownership of the project became institutionalised in the education system. At the end of the camp the people disperse back into their respective places in the system with new insights and thoughts about what might be possible. This model of innovation is slow and relies on small scale, local change at many points in a system. However, as the various actors interact with others and communicate their experiences, they begin to expand the network of those with a new vision of what is possible. **Key messages are that adults and teachers can learn much about the learning process from children who therefore must be engaged in attempts to understand the nature of teaching and learning; and that all levels of the hierarchy must be represented in attempts to bring about institutional change.**

This approach is new to South Africa, but will be used as the basis for a science camp which will be run in July of 1996. This will be done under the auspices of the Institute for Partnerships between Education and Business (Raubenheimer, 1996), with a focus on developing a more socially relevant approach to the teaching of energy and electricity. There are three main phases planned for the camp:- pre-camp activities with teachers



trying out and researching ideas in their classrooms; the science camp; and post-camp activities including teaching of new lessons, and materials development. All phases of the project will be researched. A broad range of change agents will also be involved in the project. Learnings will be fed into the development of exemplar materials and into curriculum development processes, once they become clearer.

Pareek (cited in Rodwell, 1991, p 42) adds some other key messages to the ones already given, including:- **combining central planning and development with local initiation; close ties between development and implementation agencies; promotion of organisations that are both autonomous and flexible; teacher education with incentives and without overload; adequate support material and finance; continuous feedback; and, a mechanism for regenerating the curriculum.** These are implicit from the previous sections.

## **5.9 Concluding remarks**

The proposals in this chapter clearly reject the dominant paradigm and suggestions have been made that could contribute to the creation of a new paradigm of educational innovation for South Africa, one that gives consideration to context and social relevance. It has not been the intention to provide solutions nor recommendations for curriculum change, but rather to highlight key messages which must be considered when embarking on curriculum reform at various levels in the system. These messages are driven by

examples of failure within the old paradigm and by examples of success where the old paradigm has been challenged.

The set of key messages have been derived from a broad analysis of theory and practice internationally and in developing countries, including South Africa. These key messages will be difficult to employ within a traditional paradigm, because they will be incompatible with the values, views and assumptions implicit in that paradigm. As many of the processes of curriculum development in South Africa are still located in a traditional paradigm (p 120), it will be difficult to implement these key messages within the current South African scenario. Existing conceptions and processes will need to be reviewed in order to accommodate alternative conceptions and processes of curriculum development and change. The key messages elaborated are representative of a new foundation for such policy change and action in curriculum development for primary science education. As such, the messages could be used as the basis on which to generate new policies and strategies for action.

A common element in all of these key messages is that people become actors, as individuals, and in groups. The nature of change is not predetermined but arises through deliberation between various persons involved, and is based on the consideration of appropriate local action. New ideas are communicated and promoted through a range of networks and change agents at multiple levels in the system.

This new vision of what may be possible and desirable for science education is only in an embryonic state in South Africa, with few examples of success. However, through the established science education networks it is in a slow growth phase, but this growth phase needs to be supported by government structures and policies. It is the latter that will determine whether the new approaches to curriculum innovation, to science education, and to teaching and learning, advocated in the key messages, become more broadly accepted and implemented.

## REFERENCES

- Abimbola, I O (1988) The problem of terminology in the study of student conceptions in science. Science education, 72, 2, p 175 - 184.
- Acuna, J E (1982) How concepts develop in Filipino children: Some aspects of causation. Journal of science and mathematics education in Southeast Asia, 5,1, p 18 - 27.
- Adams, R J, Doig, B A and Rosier, M (1991) Science learning in Victorian schools: 1990. Victoria: Australian Council for Educational Research.
- African National Congress (ANC) (1994) A policy framework for education and training. Johannesburg: African National Congress.
- Alberta Department of Education (1983) Elementary science curriculum guide. Edmonton: Alberta Department of Education.
- Anderson, R *et al* (1991) A triphasic model of the teaching - learning environment based on constructivist principles. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Lake Geneva, April 7 - 10, 1991 (abstract).
- Archenhold, F, Austin, R, Bell, J, Black, J, Braund, M, Daniels, S, Holding, B, Russell, A and Strang, J (1989) Assessment matters no 5: Profiles and progression in science exploration. United Kingdom: School Examinations and Assessment Council.
- Aronowitz, S (1988) Science as power: Discourse and ideology in modern society. Minnesota: University of Minnesota Press.
- Ashley, M (1989) Ideology and schooling in South African. Cape Town: South African Teachers' Association.
- African Science and Technology Education (ASTE) (1996) African Science and Technology Education Communique. Durban: University of Durban-Westville.
- Atkin, J M and Helms, J (1993) Getting serious about priorities in science education. Studies in science education, 21, p 1 - 20.
- Atkin, J M (1994) General comments based on meetings and classroom visits. Part 4 of a report prepared for an evaluation of Spider's Place materials. Johannesburg: Handspring Trust for Puppetry in Education.
- Ault, C R *et al* (1984) Constructing Vee maps for clinical interviews on molecule concepts. Science education, 68, 4, p 441 - 462 (abstract).
- Ault, C R *et al* (1988) Constructing Vee maps for clinical interviews on energy concepts. Science education, 72, 4, p 515 - 545 (abstract).

Bacchus, K (1990) Curriculum development and education in developing countries. Educational review, 42, 3, p 287 - 301.

Bajah, S T (1993) Curriculum innovations in Africa: Case studies. Paper presented at the regional conference on curriculum reforms for the 21st century, Mombasa, Kenya, 12 - 16 April, 1993.

Barber, J; Bergman, L and Sneider, C (1988) The educational effectiveness of GEMs activities. In, Great Explorations in Math and Science (GEMS: Leader's handbook. Berkley: University of California.

Barman, C R (1989) Learning about thinking and thinking about learning: New K-6 science inservice materials. The Hoosier science teacher, 1989, p 12 - 16.

Barnes, M B and Barnes, L W (1989) Observations related to teacher concept formation in an in-service setting emphasizing question-asking behaviour. Paper presented at the annual meeting of the National Association for Research in Science Teaching, San Francisco, California, 30 March - 1 April.

Barr, M, Ellis, S, Hester, H and Thomas, A (1988) Primary learning record. London: Centre for Language in Primary Education.

Barrow, L H (1989) Teaching teachers: A box of ideas. Science and children, 26, 5, p 42 - 43.

Bayona, E L M; Carter, D S G and Punch, K F (1990) The role of teachers in curriculum development. Curriculum perspectives, 1, 4, p 9 - 19.

Benson, G D (1989) Epistemology and science education. Journal of curriculum studies, 21, 4, p 329 - 344.

Berger, C F and Pintrich, P R (1986) Attainment of skill in using science processes II: Grade and task effects. Journal of research in science teaching, 23, 8, p 739 - 747.

Berkheimer, G D (1990a) Using conceptual change research to reason about curriculum. Research series number 195. East Lansing: Institute for Research on Teaching, Michigan State University.

Berkheimer, G D (1990b) Using a new model of curriculum development to write a matter and molecules teaching unit. Research series number 196. East Lansing: Institute for Research on Teaching, Michigan State University.

Berliner, D and Casanova U (1987) How do we tackle kids' science misconceptions? Instructor, 97, 4 p 14 - 15.

Bernie, H H and Ryan, A (1984) Inquiry/discovery revisited. Science and children, 21, 7, p 31 - 32.

Bhendane, L L (1996) How do English second language (ESL) students respond to ESL teachers in a primary science classroom? Unpublished research report for the Bachelor of Education degree, University of Durban-Westville.

Bhika, S; Keogh, M; Patel, F and Schrueder, R (1994) Critique, chaos and context. Paper submitted in partial fulfillment of the requirements for the Master of Education (Science Education), University of Durban-Westville.

Bot, M (1986) An overview of teacher inservice education and training (Inset) programmes in South Africa. Paper presented at the Urban Foundation workshop, Johannesburg, 17 - 18 July, 1986.

Brookes, D and Brookes, H J (1995) Constructing scientific knowledge through language. Unpublished paper, University of Durban- Westville, Durban.

Californian Department of Education (1990) Science framework for California Public Schools: Kindergarten through grade twelve. Sacramento: California Department of Education.

Cannon, R K and Padilla, M J (1982) Early adolescence: Whole body learning. Science and children, 20, 2, p 41 - 43.

Capra, F (1983) The turning point: Science, society and the rising culture. London: Fontana Paperbacks.

Carr, W and Kemmis, S (1986) Becoming critical: Education, knowledge and action research. London: Falmer Press.

Casteel, C P (1994) Reciprocal processes in science and literacy learning. The reading teacher, 47, 7, p 538 - 545.

Cavendish, S, Galton, M, Hargreaves, L and Harlen, W (1990) Assessing science in the primary classroom: Observing activities. London: Paul Chapman Publishing.

Centre for Education and Policy Development (CEPD) (1995) Curriculum framework for science and technology. Johannesburg: Centre for Education and Policy Development.

Chabane, C (1993) Action research in inservice education. Paper presented to the staff of the Primary Science Programme, Durban, May, 1993.

Chinapah, V and Miron, G (1990) Evaluating educational programmes and projects: Holistical and practical considerations. Paris: UNESCO.

Christie, P (1985) The right to learn. Johanesburg: Ravan Press.

Cleminson, A (1990) Establishing an epistemological base for science teaching in the light of contemporary notions of the nature of science and of how children learn science. Journal of research in science teaching, 27, 5, p 429 - 445.

Cohen, H G (1984) The effect of two teaching strategies utilizing manipulatives on the development of logical thought. Journal of research in science teaching, 21, 8, p 769 - 778.

Comber, M (1983) Concept development in relation to the particulate nature of matter in the middle school. Research in science and technological education, 1,1 p 27 - 39.

Cornbleth, C (1990) Curriculum in context. London: Falmer Press.

Cox, D (1990) A discussion of concept/process-based science: A science resource paper. Salem: Oregon Department of Education.

Cozzens, S E and Gieryn, T F (eds) (1990) Theories of Science in Society. Bloomington: Indiana University Press.

Cronin-Jones, L L (1991) Science teacher beliefs and their influence on curriculum implementation: Two case studies. Journal of research in science teaching, 28, 3, p 235 - 250.

Cross, R Y and Pitekethly, A (1988) Speed, education and children as pedestrians: A cognitive change approach to a potentially dangerous naive concepts. International journal of science education, 10, 5, p 531 - 540.

Curriculum Corporation (1994) Science - A curriculum profile for Australian schools. Victoria: Curriculum Corporation.

Daily News (1995) Public Comment is invited on essential alterations to school syllabuses. Daily News, 30 August, 1994.

Daily News (1996) Different approach to teaching: School experience about to change. Daily News, 2 February, 1996.

Department of Arts, Culture, Science and Technology (1996) South Africa's green paper on science and technology: Preparing for the 21st century. Pretoria: The Department of Arts, Culture, Science and Technology.

Department of Education (1995a) Interim core syllabus for general science: Standards 5,6 and 7. Pretoria: Department of Education.

Department of Education (1995b) Interim core syllabus for general science: Standards 2,3 and 4. Pretoria: Department of Education.

Department of Education (1995c) Curriculum framework for general and further education and training. Pretoria: Department of Education.

Department of Education (1996) Structures for the development of national policy regarding curriculum and related issues: Report of the consultative forum on curriculum. Pretoria: Department of Education.

Department of Education and Science (1989) Science in the national curriculum. London: Her Majesty's Stationery Office.

Driver, R (1988) Restructuring the science curriculum: Some implications of studies on learning for curriculum development. In, Innovations in science and technology education, volume II. Paris: UNESCO.

Driver, R (1992) Progression in childrens' concept formation. Paper presented to the British Council seminar on 'Developments in Primary Science Education', 11 - 22 May, 1992.

Driver, R, Asoko, H, Leach, J, Mortimer, E and Scott, P ( 1994) Constructing scientific knowledge in the classroom. Educational researcher, 10, p 5 - 12.

Driver, R and Oldham, V (1986) A constructivist approach to curriculum development in science. Studies in science education, 13, p 105 - 122.

Dyasi, H (1995) Approaches to the inservice education of primary science teachers. Paper presented at the Centre for the Advancement of Science and Mathematics Education (CASME) 10th anniversary forum, Durban, 4 August.

Eaton, J F (1983) When students don't know they don't know. Science and children, 20, 7, p 6 - 9.

Eichinger, D and Roth, K J (1991) Critical analysis of an elementary science curriculum: Bouncing around of connectedness? Elementary subject centre series, number 32. East Lansing: Centre for learning and teaching of elementary subjects, Michigan State University.

Eylon, S and Linn N C (1988) Learning and instruction: An examination of four research perspectives in science education. Review of educational research, 58, 3 p 251 - 301.

Fabiano, E (1995) Resourcing science and technology education. Paper prepared for the African Science and Education conference, Durban, 4 - 9 December, 1995.

Farnham-Diggory, S (1994) Paradigms of knowledge and instruction. Review of educational research, 64, 3, p 463 - 477.

Feldman, A and Atkin, J M (1993) Research in science education in the USA. Journal of curriculum studies, 25, 3, p 281 - 289.

Fisher, D (1990) Boundary work and science: The relation between knowledge and power. In Cozzens, S E and Gieryn, T F (eds) (1990) Theories of Science in Society. Bloomington: Indiana University Press.

Fleury, S C and Bentley, M L (1991) Educating elementary science teachers: Alternative conceptions of the nature of science. Teaching education, 3, 2, p 57 - 67.

Fullan, M (1991) The new meaning of educational change. London: Cassel Education.

Fuller, B (1987) What factors raise achievement in the third world. Review of educational research, 57, 3, p 255 - 292.



- Gabel, D L, Samuel, K V and Hunn, D (1987) Understanding the particulate nature of matter. Journal of chemical education, 64, 8, 69 - 71.
- Gabel, D L (1989) Let us go back to nature study. Journal of chemical education, 66, 9, p 727 - 729.
- Galili, I (1993) The effects of prior knowledge and instruction on understanding image formation. Journal of research in science teaching, 30, 3, p 271 - 301.
- Gallagher, J J (1991) Prospective and practising secondary school science teachers' knowledge and beliefs about the philosophy of science. Science education, 75, 1, p 121 - 133.
- Garrett, R M (1990) The introduction of school-based curriculum development in a centralised education system: A possible tactic. International journal for educational development, 10, 4, p 303 - 309.
- Garver, J B (1983) Early adolescence: Minerals and formal thought. Science and children, 21, 1, 54 - 56.
- Gilbert, J (1995) Teacher development for a constructive future. Paper presented at the 16th National Convention of Natural Science and Mathematics Education Associations of South Africa, 9 - 14 July.
- Giroux, H A (1981) Towards a new sociology of curriculum. In Lawn, M and Barton, L (eds) (1981) Rethinking curriculum studies. London: Groom Helm.
- Giroux, H A, Penna, A N and Pinar, W F (1981) Curriculum and instruction. Berkley: McCuthchan Publishing Corporation.
- Goldsworthy, A and Feasey, R (1994) Making sense of primary science investigations. Hatfield: The Association for Science Education.
- Goodson, I F (1990) Studying curriculum: Towards a social constructionist perspective. Journal of curriculum studies, 22, 4, p 299 - 312.
- Goodson, I F (1994) Studying Curriculum. Buckingham: Open University Press.
- Goodwin, A J and Taylor, J C (1992) Supporting the inservice education of teachers, with particular focus upon transfer between developed and developing countries. Manchester: Department of Sciences Education, The Manchester Metropolitan University.
- Gott, R and Murphy, P (1987) Assessing investigations at ages 13 and 15. Science report for teachers: 9. London: Assessment of Performance Unit, Department of Education and Science.
- Gough, A G and Robottom, I (1993) Towards a socially critical environmental education: water quality in a coastal school. Journal of curriculum studies, 25, 4, p 301 - 316.

Greenland, J (1983) The inservice training of teachers in English-speaking Africa. London: MacMillan.

Gribbin, J (1984) In search of Schrodinger's cat: Quantum physics and reality. London: Black Swan Books.

Gross, N; Giaquinta, J B and Bernstein, M (1969) Implementing organisational innovations: A sociological analysis of planned educational change. New York: Basic Books Incorporated.

Grundy, S (1987) Curriculum: Product of praxis. London: Falmer Press.

Guba, E C and Lincoln, Y S (1989) Fourth generation evaluation. London: Sage Publications.

Guba, E C (1990) The alternative paradigm dialog. London: Sage Publishing.

Handspring Trust for Puppetry in Education (1994) How do teachers use innovative primary science materials: Report on an evaluation of 'Spider's Place'. Johannesburg: Handspring Trust for Puppetry in Education.

Hargreaves, A (1994) Critical introduction. In Goodson, I F (1994) Studying Curriculum. Buckingham: Open University Press.

Harlan, J (1988) Science experiences for the early childhood years (fourth edition). Columbus: Merrill Publishing Company.

Harlen, W (1978) Does content matter in primary science? School science review, 59, p 614 - 625.

Harlen, W (1983) Science at age 11. Science report for teachers: 1. London: Assessment of Performance Unit, Department of Education and Science.

Harlen, W (1993) Teaching and learning primary science. London: Paul Chapman Publishing.

Harlen, W and Elstgeest, J (1992) UNESCO sourcebook for science in the primary school: A workshop approach to teacher education. Paris: UNESCO Publishing.

Harlen, W and Osborne, R (1983) Towards a teaching model for primary science: Learning in Science Project (Primary), working paper, number 114. Hamilton: Science Education Research Unit, Waikato University.

Harlen, W, Palacio, D and Russell, T (1984) Science assessment framework age 11. Science report for teachers: 4. London: Assessment of Performance Unit, Department of Education and Science.

Harvey, S (1994) The use of diagnostic questionnaires in Primary Science Programme workshops. Durban: Primary Science Programme.

Harvey, S (1996) Class roots INSET: Classroom support for assisting teachers to change. Paper presented at the SAARMSE conference, January 1996.

Hashweh, M (1988) Descriptive studies of students' conceptions in science teaching. Journal of research in science teaching, 25, 2, p 121 - 134.

Hass, G (1983) Curriculum planning: A new approach (4th edition). Boston: Allyn and Bacon.

Hassard, J (1993) Sociology and organisational theory: Positivism, paradigms and postmodernity. Cambridge: Cambridge University Press.

Havelock, R G (1971) The utilisation of educational research and development. British journal of educational development, 2,2 p

Hawes, H and Stephens, D (1990) Questions of quality: primary education and development. Harlow, Essex: Longman Group.

Head, J (1986) Research into 'alternative frameworks': Promise and problems. Unknown source.

Herget, D E (1989) Towards a philosophical basis for science education of the 1990s: An African view-point. Paper presented at the first International Conference on the History and Philosophy of Science in Science Teaching.

Hlebowitsh, P S (1992) Amid behavioural and behaviouristic objectives: Reappraising appraisals of the Tyler rationale. Journal of curriculum studies, 24, 6, p 533 - 547.

X Hodson, D (1988) Towards a philosophically more valid science curriculum. Science education, 72, 1, p 19 - 40.

Hofmeyer, J (1994) Educating the educators. In, Sonn, F (ed) Reconstructing education. Cape Town: IDASA.

Holbrook, J (1991) Project 2000+: Scientific and technological literacy for all. Paper presented at the International Conference for Science, Technology and Mathematics Education, 27 June - 1 July, 1991, Gaborone, Botswana.

Hopkins, D (1995) Powerful learning, powerful teaching and powerful schools. A paper presented at a series of seminars for the Institute for Partnerships between Education and Business, 11 - 13 December, 1995.

House, E R (1979) Technology versus craft: A ten year perspective on innovation. Journal of curriculum studies, 11, 1, p 1 - 15.

Howard, R H (1989) What is 'understanding' in science teaching and how can it be promoted? School science review, 70, 252, p 116 - 119.

Hull, R (1990) Science, technology and society. Salem: Oregon Department of Education.

Hungwe, K (1994) A decade of science education in Zimbabwe (1980 - 1990): Nationalist vision and post-colonial realities. Journal of curriculum studies, 26, 1, p 83 - 95.

International Development Research Centre (IDRC) (1993) Towards a science and technology policy for a democratic South Africa: Mission Report. Ottawa: IDRC.

Jansen, J (1989) Curriculum reconstruction in post-colonial Africa: A review of the literature. International journal for educational development, 9, 3, p 219 - 231.

Jansen, J (1994) Teachers in curriculum development. Key note address, presented at the PRAESA conference, Durban, 6 - 9 July, 1994.

Jansen, J (1995) 'Essential alterations?' A critical analysis of the state's syllabus revision process. Paper presented to a meeting of the Teacher's League of South Africa, 12 July, 1995.

Jarvie, I C (1983) Realism and the supposed poverty of sociological theories. In, Cohen, R S and Wartofsky, M W (eds) Epistemology, methodology and the social sciences. Dordrecht, Holland: D Reidel Publishing Company.

Jegede, O (1995) The knowledge base for learning in science and technology education. Discussion paper prepared for the African Science and Technology Education conference, Durban, 4 - 9 December, 1995.

Jenkins, E W (1992) School science education: Towards a reconstruction. Journal of curriculum studies, 24, 3 p 229 - 246.

Joyce, T and Peacock, G (1993) Progression in childrens' ideas about living things. Primary science review, 29, 10, p 18 - 19.

Kahn, M (1991) Development, dependency and science education: A Botswana case study, working paper no. 56. Gaborone: National Institute of Development Research and Documentation, University of Botswana.

Kahn, M; Levy, S; Rollnick, M; Segall, R and Kotecha, P ( 1992) Some insights into the problems facing science education and possible policies to address them: Science curriculum group report. Cape Town: National Education Policy Initiative.

Kay, S (1975) Curriculum innovations and traditional culture: A case study of Kenya. Comparative education, 11, 3, p 183 - 190.

King, M and Van den Berg, O (1992) The politics of curriculum: Structures and processes, focus series one. Pietermaritzburg: Centaur Publications.

Kolesar, P T (1989) Role of geology in science teaching. Journal of geological education, 37, 5, p 312 - 313.

Kruger, C and Summers, M (1988) Some primary school teachers' understanding of the conceptions of force and gravity. Primary school teachers and science project. Oxford: Department of educational studies, University of Oxford.

Kruger, C (1989) The 'material' interviews - detailed findings. Primary school teachers and science project. Oxford: Department of educational studies, University of Oxford.

Kruger, C and Summers, C (1989) An investigation of some primary teachers' understanding of changes in materials. School science review, 71, 255, p 17 - 27.

Kuhn, T S (1970) The structure of scientific revolutions, 2nd ed. Chicago: University of Chicago Press.

Lange, R V ( 1995) How do systems of education change and how shall we change our own? Some modest generalisations. Paper presented at the 16th National Convention of the Federation of Natural Science and Mathematics Education Associations of South Africa.

Lapp, D (1995a) Views on developments in natural sciences. Paper presented at the Centre for the Advancement of Science and Mathematics Education's (CASME) 10th anniversary forum, Durban, 4 August.

Lapp, D (1995b) Curriculum innovations and their impact on teaching of science and technology. Discussant response to a paper prepared by M Savage for the African Science and Technology Education conference, 4 - 9 December, 1995.

Lawson, A E (1986) Integrating research on misconceptions, reasoning patterns and three types of learning cycles. Paper presented at the United States-Japan Seminar on science education, Honolulu, September (abstract).

Lawson, A E (1988) The acquisition of biological knowledge during childhood: Cognitive conflict or tabula rasa? Journal of research in science teaching, 25, 3, p 185 - 199.

Lawson, A E (1989) A theory of instruction: Using the learning cycle to teach science concepts and thinking skills. National Association for Research in Science Teaching, Monograph number 1, p 1 - 136.

Learning in Science Project (Primary) (1982) Learning in Science Project (Form 1 - 4): Final Report. Hamilton: Science Education Research Unit, Waikato University, New Zealand.

Leriché, L W (1990) The sociology of the curriculum. Educational research and perspectives, 17, 2, p 60 - 69.

Levy, S (1989) A critical appraisal of the 1978 South African Association for Teachers of Physical Science document's recommendations for science education in South Africa. Unpublished Master of Education thesis, University of the Witwatersrand, Johannesburg.

Lewin, K M and Stuart, J S (1991) Educational innovation in developing countries. London: The MacMillan Press.

Lewin, K (1992) Science education in developing countries: Issues and perspectives for planners. Paris: UNESCO.

Lewin, K (1993) Planning policy on science education in developing countries. International journal of science education, 15, 1, p 1 - 5.

Lewin, K (1994) Science and technology policy in relation to education. Paper presented to a seminar held at the University of Durban-Westville, 1 June, 1994.

Lincoln, Y S (1990) Judging the quality of case-study reports. Qualitative studies in education, 3, 1 p 55 - 59.

Lindberg, D H (1990) What goes 'round comes 'round doing science. Childhood education, 67, 2, p 79 - 81.

Lockheed, M E and Verspoor, A M (1991) Improving education in developing countries: Issues and perspectives for planners. Paris: UNESCO.

London, N A (1993) Why education in developing countries fail: A case study. International journal of educational development, 13, 3, p 265 - 275.

Longino, H E (1990) Science as social knowledge: Values and objectivity in scientific inquiry. Princeton: Princeton University Press.

Lowery, L F (1992) The scientific thinking processes. Full option science system, Lawrence Hall of science. Berkley: University of California.

MacDonald, C A (1990) Standard three general science research. Pretoria: Human Sciences Research Council.

Masters, J (1994) Measuring conceptual understanding. Paper presented at the ex-Natal Education Department Subject Advisory offices.

Matthews, M R (1992) Constructivism and empiricism: An incomplete divorce. Research in science education, 22, p 299 - 307.

McGuigan, L (1990) Words, words, words. Primary science review, 14, 10, p 32 - 33.

McNaught, C; Raubenheimer, C D and Keogh, M (1989) A general science syllabus; Standards 3 to 7: Report of a workshop held at Michaelhouse, Natal on 11 - 12 January 1989. Durban: Science Curriculum Initiative in South Africa.

McNaught, C and Raubenheimer, C D (1991) Critical reflections on teachers in action: An evaluation report of the Natal Primary Science Project. Durban: The Urban Foundation.

Mechling, K R and Oliver, D L (1983) Who is killing your science program? Science and children, 21, 2, p 15 - 18.

Meinhard, R (1989) Contributions of Piaget to science education: Science curriculum concept paper, 2, p 1 - 12. Salem: Oregon Department of Education.

Meinhard, R (1992) Concept/process based science in the elementary school: Science curriculum concept paper, 5, 1 - 12. Salem: Oregon Department of Education.

Metz, K (1995) Reassessment of developmental constraints on children's science instruction. Review of educational research, 65,2, p 93 - 127.

Mhlongo, N and Hlatswayo, T (1995) School and classroom support. Paper presented at the 16th National Convention of the Federation of Natural Science and Mathematics Education Associations of South Africa.

Millar, R and Driver, R (1987) Beyond processes. Studies in science education, 14, p 33 - 62.

Millar, J P and Seller, W (1985) Curriculum: Perspectives and practice. New York: Longman.

Minstrell, J and Smith, C (1983) What research says: Alternative conceptions and a strategy for change. Science and children, 21, 3, p 31 - 33.

Monroe, M C and Kaplan, S (1988) When words speak louder than actions: Environmental problem solving in the classroom. Journal of environmental education, 19, 3, p 38 - 41.

Moulton, J (1994) How do teachers use textbooks and other print materials? A review of the literature. Paper prepared for the Improving Education Quality (IEQ) project. Durban: IEQ.

Murphy, P and Gott, R (1984) Science assessment framework age 13 and 15. Science report for teachers: 2. London: Assessment of Performance Unit, Department of Education and Science.

National Education Policy Initiative (NEPI) (1992) Curriculum. Cape Town: Oxford University Press.

National Professional Teachers' Association of South Africa (NAPTOSA) (1996) Information - January/February 1996. Arcadia: NAPTOSA.

National Science Resource Centre (1994) Science and technology for children: An innovative, hands-on elementary science curriculum program. Washington: National Science Resource Centre.

Ndimande, S F (1996) Investigating the role of the teachers in inservice education and training for teachers of physical science in the Zululand region of KwaZulu Natal: A case study of CASME workshops from 1994 to 1995. Unpublished Master of Education thesis, University of Durban-Westville, Durban.

Neale, D C (1990) Implementing conceptual change teaching in primary science. Elementary school journal, 91, 2, p 109.

Nel, D (1989) Refractions in reality. Unpublished monograph, University of Natal, Durban.


Newton-Smith, W H (1981) The rationality of science. London: Routledge and Kegan Paul.

Noori, K (1993) Authentic assessment in elementary science. Unknown source.

Nuffield Chelsea Curriculum Trust (1993a) Nuffield Primary Science Processes and Concept Exploration: Teachers' Handbook. London: Collins Educational.

Nuffield Chelsea Curriculum Trust (1993b) Nuffield Primary Science Processes and Concept Exploration: In-service pack. London: Collins Educational.

Ogunniyi, M B (1995) In search of an appropriate knowledge base for learning in science and technology in Africa. Discussant response to a paper prepared by Prof O Jegede, African Science and Technology Education conference, 4 - 9 December, 1995.

 Oregon Department of Education (1988) Developing science education goals: Science curriculum concept paper, 1. Salem: Oregon Department of Education.

Oregon Department of Education (1990) Concept/process-based science: Science curriculum concept paper, 4. Salem: Oregon Department of Education.

Osborne, R (1983) Towards modifying children's ideas about electricity. Research in science and technological education, 1,1, p 73 - 82.

Osborne, R (1984) Childrens' dynamics. Physics teacher, 22, 8, p 504 - 508.

Osborne, R and Freyberg, P (1985) Learning in science: The implications of children's science. London: Heinemann.

Osborne, J, Black, P, Smith, M and Meadows, J (1990) SPACE Research Reports: Light. Liverpool: Liverpool University Press.

Osborne, J (1991) Approaches to the teaching of AT16 - the earth in space: Issues, problems and resources. School science review, 72, 260, p 7 - 15.

Osborne, J, Black, P, Smith, M and Meadows, J (1991) SPACE Research Reports: Electricity. Liverpool: Liverpool University Press.

Osborne, J, Wadsworth, p and Black, P (1992) SPACE Research Reports: Processes of life. Liverpool: Liverpool University Press.

Osborne, J (1993) Alternatives to practical work. School science review, 75, 271, p 117 - 123.

Papagiannis, G J, Klees, S J and Bickel, R N (1982) Towards a political economy of educational innovation. Review of educational research, 52, 1, 245 - 290.

Peacock, A (1986) Science skills: A problem solving activity book. London: MacMillan Educational.

Peacock, A (1993) A global core curriculum for primary science. Primary science review, 28, 6, p 8 - 9.



Peacock, A (1994a) Primary science in Africa. Paper presented at the SAARMSE conference, Durban, 27 - 30 January 1994.

Peacock, A (1994b) The significance of implementation in relation to introducing new educational materials in primary science classrooms. Unpublished report written for the Primary Science Programme, Johannesburg, South Africa.

Peacock, M (1994) Toyota Teach Primary School Project: Evaluation of project impact on wave 1 schools. Durban: Toyota Teach.

Pines, A L and Novak, J D (1985) The instruction of audio-tutorial instruction with student prior knowledge: A proposed qualitative case-study methodology. Science education, 69, 2, p 213 - 228.

Popkewitz, T S (1984) Paradigm and ideology in educational research. London: Falmer press.

Proctor, R N (1991) Value-free science? Purity and power in modern knowledge. Cambridge: Harvard University Press.

Psacharopoulos, G and Woodhall, M (1985) Education for development: An analysis of investment choices. London: Oxford University Press.

Punch, K F and Bayona, E L M (1990) Teacher participation in curriculum development: A model and field study in Tanzania. International journal of educational development, 10, 4, p 253 - 267.

Putsoa, B (1995) Historical perspectives and their relevance to present and future practice. Discussant response to a paper prepared by Prof E A Yoloye, African Science and Technology Education conference, 4 - 9 December, 1995.

Rakow, S J (1986) Teaching science as inquiry. Bloomington: Phi Delta Kappa Educational Foundation.

Raubenheimer, C D (1992/1993) An emerging approach to teacher development: Who drives the bus? Perspectives in education, 14, 1, p 67 - 80.

Raubenheimer, C D (1993) Lesson plans for teachers written by teachers: A lesson for material developers. Paper prepared for the degree of the Master of education.

Raubenheimer, C D (1994) An alternative framework for curriculum reconstruction. Paper presented at the first Port Elizabeth science teachers' convention, 3 - 4 October, 1994.

Raubenheimer, C D (1995a) A critique of 'Primary Science Through Activity' by J Wilkinson. Unpublished report written for MacMillan Boleswa, Johannesburg, South Africa.

Raubenheimer, C D (1995b) Proceedings of the 'Workshop on workshops', 6 - 8 July 1995. Durban: Primary Science Programme.

- Raubenheimer, C D (1995c) Proceedings of the school and classroom support working group. Durban: Primary Science Programme.
- Raubenheimer, C D (1996) Eskom energy and electricity project: Project proposal. Durban: Institute for Partnerships between Education and Business.
- Reid, W A (1992) The state of curriculum inquiry. Journal of curriculum studies, 24, 2, p 165 - 177.
- Republic of South Africa (1995) White paper on education and training, 15 March, 1995. Pretoria: Department of Education.
- Richards, S (1983) Philosophy and sociology of science: An introduction. Oxford: Basil Blackwell.
- Riddle, B (1988) E T, Call home ... or Phoenix, or Burbank. Science and children, 25, 4, 30 - 33.
- Roberts, D A (1982) Developing the concept of 'curriculum emphases' in science education. Science education, 66, 2, p 243 - 260.
- Rodwell, S (1991) The theory and practice of introducing change. In, Little, A and Yates, C (eds) Education and development. London: DICE/IEC/University of London.
- Rogan, J M and Luckowski, J A (1990) Curriculum texts: The portrayal of the field. Part 1. Journal of curriculum inquiry, 22, 1, p 17 - 39.
- Rollnick, M and Reddy, V (1995) Relevance and promotion of equity. Discussion paper prepared for the African Science and Technology Education conference, Durban, 4 - 9 December, 1995.
- Ross, K A (1988) Matter scatter and energy anarchy: The second law of thermodynamics is simply common experience. School science review, 69, 248, p 438 - 445.
- Roth, K (1985a) Food for plants: Teacher's Guide. Research series number 153. East Lansing: Institute for Research on Teaching, Michigan State University.
- Roth, K (1985b) Conceptual change learning and student processing of science texts. Paper presented at the annual meeting of the American Educational Research Association, Chicago, April (abstract).
- Roth, K (1989) Science education: It's not enough to 'do' or 'relate'. American educator: The professional journal of the American Foundation of Teachers, 13, 4, p 16 - 22.
- Rouse, J (1987) Knowledge and power: Towards a political philosophy of science. Ithaca: Cornell University Press.
- Russell, T and Harlen, W (1990) Assessing science in the primary classroom: Practical tasks. London: Paul Chapman Publishing.

Russell, T and Watt, D (1990) SPACE Research Report: Growth. Liverpool: Liverpool University Press.

Russell, T and Watt, D (1991) SPACE Research Report: Evaporation and condensation. Liverpool: Liverpool University Press.

Russell, T Longden K and McGuigan, L (1991) SPACE Research Report: Materials. Liverpool: Liverpool University Press.

Russell, T, Qualter, A, McGuigan, L and Ewart, M (1993) Evaluation of science in the National Curriculum: Third interim report - Progression. Liverpool: CRIPSAT, University of Liverpool.

Russell, T (1993) Improving classroom practices in primary science: The potential contribution of action research to indigenous curriculum reform. Background paper for the ICASE/UNESCO International Forum for Project 2000, Paris 5 - 10 July, 1995.

Savage, E M (1995) Curriculum innovations and their impact on teaching of science and technology. Discussion paper prepared for the African Science and Technology Education (ASTE) conference, 4 - 9 December, 1995.

Sawyer, E S (1985) The secondary curriculum and the secondary student in Sierra Leone. Science education, 69, 2, p 147 - 153.

Schilling, M, Hargreaves, L, Harlen, W and Russell, T (1990) Assessing science in the primary classroom: Written tasks. London: Paul Chapman Publishing.

Science Curriculum Initiative in South Africa (SCISA) (1992) Reality to rhetoric: Report of a workshop held in June 1992. Durban: SCISA.

Science Curriculum Initiative in South Africa (SCISA) (1994) SCISA writing circles: Report of a workshop held on 26 & 27 January 1994. Durban: SCISA.

Science Curriculum Initiative in South Africa (SCISA) (1996) Minutes of the SCISA Board meeting, February, 1996. Durban: SCISA.

Schubert, W H (1986) Curriculum: Perspective, paradigm and possibility. New York: MacMillan.

Schwab, J J (1974) Decision and choice: The coming duty of science teaching. Journal of research in science teaching, 11, 4 p 309 - 317.

Scott, P, Dyson, T and Gater, S (1987) A constructivist view of learning and teaching science. University of Leeds: Children's learning in science project.

Shah, S (1994) Classroom science for equality and justice. Paper presented to the staff of the Primary Science Programme.

Shaw, E L and Cronin-Jones, L (1989) Influence of methods instruction in pre-service elementary and secondary science teachers' beliefs. Paper presented at the Annual Meeting of the Mid-South Educational Research Association, Little Rock, Arizona, November 7 - 10.

Shymansky, J A (1989) About ESS, SCIs, and SAPA. Science and children, 26, 7, p 33 - 35.

Simons, H (1987) Getting to know schools in a democracy. London: Falmer Press.

Smith, D C (1984) Cognitive processes and students' misconceptions in science. Paper presented at the annual meeting of the Northeastern Education Research Association, New York, October 25.

Smith, E L and Anderson, C W (1984a) Plants as producers: A case study of elementary science teaching. Journal of research on science teaching, 21, 7, p 685 - 698.

Smith, E L and Anderson, C W (1984b) The planning and teaching intermediate science study: Final report. Institute for research on teaching, Michigan State University, Research series, number 147.

Smith, R and Peacock, G (1995) Investigations and progression in science. London: Hodder and Stoughton.

Sneider, C and Pulos, T (1983) Children's cosmographies: Understanding the earth's shape and gravity. Science education, 67, 2, p 205 - 221.

Solomon, J (1983) Messy, contradictory and obstinately persistent: A study of children's out-of-school ideas about energy. School science review, 65, 231, p 225 - 229.

Solomon, J (1994) The rise and fall of constructivism. Nafferton: Studies in science education.

Soltis, J F (1984) On the nature of educational research. Educational researcher, December, p 5 - 10.

Staver, J R and Bat, M (1989) Analysis of the conceptual structure and reasoning demands of elementary texts at the primary (K-3) level. Journal of research in science teaching, 26, 4, p 329 - 349

Stavy, R (1984) Children's conception of gas. International journal of science education, 10, 5, p 553 - 560.

Stenhouse, L (1978). An Introduction to Curriculum Research and Development. London: Heinemann.

St. John, M (1991) Perspectives on systemic change. In, Science education for the 1990s: Strategies for change. Inverness, California: Inverness Research Associates.

Steiner, R (1984) Chemistry for kids: Chemistry in the kindergarten classroom. Journal of chemical education, 61, 11, 1013 - 1014.

Stockman, N (1983) Antipositivist theories of the sciences. Dordrecht: D. Reidel Publishing Company.

Stoddart, T *et al* (1993) Reconstructing elementary teacher candidates' understanding of mathematics and science content. Teaching and teacher education, 9, 3, p 229 - 241 (abstract).

Strawitz, B M and Malone, M R (1987) Preservice teachers' acquisition and retention of integrated science process skills: A comparison of a teacher-directed and self-instructional strategies. Journal of research in science teaching, 24, 1, p 53 - 60).

Swang, J (1993) Portfolios: Windows on learning. Ensuring success in science. Learning, 21, 8, p 24 - 26

Teters, P and Gabel, D (1984) 1982-1983 results of the NSTA survey of needs of elementary teachers regarding the teaching of science. Washington: National Science Teachers Association.

Tobin, K (1994) Impediments to the improvement of teaching and learning practices in science classrooms in developing countries. Paper presented at the National Association of Research in Science Teaching conference, Annenheim, April, 1994.

Torrance, H (1991) Reports - Assessment: Introduction. Journal of curriculum studies, 23, 6, p 537 - 557.

Trowbridge, J E and Mintzes, J J (1985) Students' alternative conceptions of animals and animal classification. School science and mathematics, 85, 4, p 304 - 316.

Urevbu, A O (1984) Teaching concepts of energy to Nigerian children in the 7 - 11 year-old age range. Journal of research in science teaching, 21, 3, p 255 - 267.

van Cleaf, D and Hamilton, P (1988) Taking heart in hand. Science and children, 25, 5, p 30 - 31.

van Rooyen, H (1990) The disparity between English as a subject and English as the medium of learning. Pretoria: Human Sciences Research Council.

Varda, B (1989) Introducing mechanics at the elementary school. Physics education, 24, 6, 348 - 352.

Vygotsky, L (1967) Thought and language.

Warren, B, Puttick, G M, Conant, F R and Rosebery, A S (1992) Sense-making practices in science: Case study of an ESL teacher. Hands on, 15, 2, p 4 - 6.

Warwick, D P (1982) Bitter Pills: Population policies and their implementation in eight developing countries. New York: Cambridge University Press.

Watkinson, A (1991) Primarily assessing Education in science, 141, 1, p 8 - 9.

- Watson, B (1994) Switch off kids' science misconceptions. Learning, 22, 5, p 74 - 76.
- Watt, D M (1980) An exploration of students' understanding of the concepts of 'force' and 'energy'. Paper presented at the International Conference on Education for Physics Teaching, International Commission for Physics Education, Trieste, Italy, September 1 - 6.
- Watt, D M and Pope, M (1989) Thinking about thinking, learning about learning: Constructivism in physics education. Physics education, 24, p 326 - 331.
- Watt, D and Russell, T (1990) SPACE Research Reports: Sound. Liverpool: Liverpool University Press.
- Wilkinson, J W (1994a) Primary science through activity: Lower primary. Hong Kong: MacMillan Educational Australia.
- Wilkinson, J W (1994b) Primary science through activity: Upper primary. Hong Kong: MacMillan Educational Australia.
- Williams, K (1986) An implementation study: An analysis of elementary student and teacher attitudes towards science in process-approach vs traditional science classes. Unknown source.
- Wilson, J T and Chalmers-Neubauer, I (1990) A comparison of teacher roles in three exemplary hand-on elementary science programs. Science education, 74, 1, p 69 - 85.
- Yager, R E (1991) The constructivist learning model. The science teacher, 9, p 52 - 57.
- Yerrick, R and Nugent, J (1996) Does a multicultural treatment of science guide or disguise classroom dilemmas? Science education international, 7, 1, p 13 - 17.
- Yoloye, A (1977) Evaluation of the African Primary Science Programme (APSP). In, Cohen, D (ed) New trends in integrated science teaching, vol IV. Paris: UNESCO.
- Yoloye, A (1995) Historical perspectives and their relevance to present and future practice. Paper prepared for the African Science and Technology Education conference, Durban, 4 - 9 December, 1995.
- Young, B L (1979) Teaching primary science. Hong Kong: Longman Group.
- Young, M F D (ed) (1971) Knowledge and control. London; Collier-MacMillan.
- Zukav, G (1979) The dancing Wu-Li masters: An overview of the new physics. London: Fontana Paperbacks.