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**INNOVATION IN SCIENCE CURRICULUM
A SIERRA LEONE CASE STUDY**

**A thesis submitted in fulfilment
of the requirements
for the
Degree of Doctor of Philosophy
at the
University of Waikato**

by

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To The Living Memory

of

The Late JONATHAN BUNDOR

A B S T R A C T

Recent studies in philosophy of science and learning theory have identified elements that add a socio-cultural dimension to science curriculum debates. These suggest that effective science education must take account of the culture in which it is being offered. Accordingly, the present study conducted in Sierra Leone investigated the viability of a junior secondary school science curriculum that took into account the childrens' traditional culture.

The investigation involved two parts. The first was a case study examining the present state of junior secondary school science education in Sierra Leone using data derived from a survey which canvassed teachers' perceptions of science and students' attitudes towards it. The second involved action research in which a group of teachers worked with the researcher to develop, trial and self-evaluate teaching packages in physics based on the Science for All curriculum, an approach that is based on the constructivist view of learning. The main intent of the study was to investigate first, the effects on their professional development of the teachers' interaction with the new curriculum and, secondly, their students' attitudes towards science. The research instruments employed were interviews, classroom observation and an attitudes to science questionnaire.

The initial case study showed that the present junior secondary school science programme in Sierra Leone was characterised by:

1. Unfavourable students' attitudes towards science.
2. Low numbers of General Science teachers with subject expertise in Physics and Chemistry.
3. A lack of sense of direction in determining goals and objectives.
4. Inadequate pre-service teacher education preparation.
5. Limited teacher understanding of recent changes in the thinking about the nature of science and the ways of acquiring scientific knowledge.

Successful use of the new curriculum to overcome these problems was hindered by the teachers' scepticism about the new curriculum, a gap between their theoretical and practical understanding of the change process, and insufficient skills to implement the revised curriculum. Techniques employed to alleviate these problems during the action research suggested that teachers' commitment could be increased by clarifying conceptually the need for innovation. The researcher's support and encouragement throughout the curriculum trials significantly helped teachers to give practical expression to their theoretical understanding of the change process.

Action research with the new curriculum brought about major changes in the teachers' approach to teaching. They showed evidence of appreciating recent constructivist views about the nature of science and the ways of acquiring scientific knowledge. The development of their own effective and more relevant curriculum also enhanced the teachers' self esteem. But even though the teachers with their new found confidence believed otherwise, post-test results showed that students' attitudes to science were not enhanced by their interaction with the new curriculum.

The results of the study suggest policy implications for Sierra Leone. The educational system and science curricula need to dwell far less on western-type syllabuses and public examinations and develop instead science curricula that bridge school science and students' everyday application of scientific ideas in their traditional settings.

Nevertheless, much research is required to identify cultural aspects that can be linked to the school science curriculum. Concomitantly, there is need to research the viability of both preservice and inservice teacher education programmes that can bring about the bridging referred to. The present action research study is a beginning.

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CHAPTER 1: INTRODUCTION

1.1 THE RESEARCH PROBLEM AND RELATED BACKGROUND

I did not know before that the purpose of teaching science was to enable students to apply the ideas they are taught in real life. To me, science lessons were some sort of packages, collected from textbooks and handed over to the students.

(Case Study Teacher)

If the golden age of science curriculum reforms in the post-Sputnik era held any lesson, it was that there is no such thing as a teacher-proof programme. Teachers are the key to what happens in the science classroom, and their attitudes, perceptions and skills are crucial for curriculum innovation decisions.

The quotation above by one of the science teachers in the present study does not seem to reflect this recognition. On the contrary, it manifests the disparity between Sierra Leonean science teachers' philosophy about secondary school science teaching and current international awareness to ground the teaching and learning of science in learners' meaningful experiences.

In spite of attempts at curriculum innovation, science education in Africa remains largely unsatisfactory. This could possibly be due to the fact that most of these innovations have been contemplated by western scientists and imposed on African science teachers without knowledge of ideological reasons underlying the changes. Consequently, African science teachers have found it easier to maintain the mainstream of curricula they are familiar with - which are those they studied as students, than attempt to blaze new trails. To avoid the mistake of the past calls for new curriculum innovation strategies in Africa, such as the one attempted in the present study.

The late 1960s and early 1970s marked the period of academic imperialism (Kelly and Altbach, 1978) during which many so-called progressive science curricula developed in Western countries found their way in African science classrooms. Earlier dissatisfaction with these curricula was usually directed at the syllabuses, teaching

methods, textbooks etc. However, the 1980s witnessed a growing awareness that for science education to be effective, it must take much more explicit account of the cultural contexts of the society which provides its setting, and whose needs it exists to serve (Maddock, 1981). Before that time, the focus of science curriculum innovation remained mostly on the nature of the discipline, rather on the nature or circumstances of the learners. No accounts were taken in the majority of the curriculum projects of the experiences that children bring to school (Young, 1973).

Chaplin (1964) reported that textbooks were conceived without taking the cultural background or personal experiences of the traditional African learners into considerations, and the purpose of studying science often seemed misguided. Cole (1975) reported that science was taught at secondary schools in traditional societies not for the purpose of gaining usable knowledge and skills that would enhance rural transformation, but for preparing students for public examinations. Hewson (1986) claimed that most westernised science curricula did not encourage students in traditional societies to think scientifically in contexts of their own cultures. These and other considerations have given cause for new curriculum reconsiderations in non Western countries. Indeed, science education journals now feature accounts of the effects of culture on science learning, and calls to reduce conflicts between school science and traditional children's everyday explanations of natural phenomena (Gallagher and Dawson, 1984; Jegede and Okebukola, 1988).

Another dimension that has added support for socio-cultural considerations in science curriculum is the emerging views about learning. Over the last decade, the empiricist-inductivist tradition which places no emphasis on the learner's own conceptions and active participation in the learning process has been challenged by constructivists.

The constructivist tradition is concerned about the intents, beliefs and emotions of individuals as well as their conceptualisations, and recognises the influence that prior experience has on the way phenomena are perceived and interpreted (Driver and Oldham, 1985). Proponents of this school argue that children long before formal science education construct for themselves intuitive interpretations of and explanations for many natural phenomena based on their direct

and informal social interactions. This realisation has surmounted to a view of science learning as conceptual change rather than concept acquisition (Cosgrove and Osborne, 1985; Larsson, 1983; Posner and Bertzog, 1982; Hewson, 1981; Shuell, 1987).

The constructivist view of learning has implications for our view of the curriculum (Posner, 1982). From a constructivist perspective, the learner constructs his or her knowledge and what is constructed, the meanings that are made, depends on what the learner brings as well as the learning situation provided. In this circumstance, the curriculum is the set of learning experiences which enable the learners to develop their understanding (Driver and Oldham, 1985). Consequently, unlike Morehouse (1967) or Ziman (1969) who expressed optimism that science curricula are sufficiently culture free to be able to adapt relatively easily to new cultural contexts, the above arguments would suggest otherwise.

Unfortunately, few educational studies have been undertaken either in the production of curriculum materials or teacher education programme that incorporate traditional children's everyday experiences in the teaching-learning of science. According to Fensham (1985, pp.418-419), the secondary school curriculum in mathematics and science in many countries was characterised among others by the following:

1. *It involves the rote recall of a large number of facts, concepts and algorithms that are not obviously socially useful.*
2. *It involves too little familiarity with many of the concepts to enable their scientific usefulness to be experienced.*
3. *It involves life experiences and social applications only as exemplary rather than as the essence of the science learning.*

It was this concern above, together with the paucity of research about this concern in many African countries in particular, that gave rise to this study.

1.2 PURPOSE OF THE STUDY

There could be no better experts to design a curriculum that bridges traditional children's real life experiences with school science than the local teachers who know the two world views of these children. Consequently, it was decided to provide a group of teachers with a conceptual framework that would guide the development and teaching of such a curriculum. To this end, a constructivist Science for All curriculum model was adopted.

The present study therefore entailed science teachers using that model to develop a General Science Curriculum for the junior secondary school level in Sierra Leone, and carry out an experimental investigation on the appropriateness of that curriculum. This required:

- (i) providing the teachers with a non-threatening atmosphere in which they could consciously make public the weaknesses of the existing General Science Curriculum, in readiness for introducing them to an alternative constructivist curriculum model;
- (ii) providing experiences that would enable the teachers to develop an understanding of the constructivist Science for All ideology, to enable them develop a new curriculum based on that model; and
- (iii) engaging teachers in trialling of the new curriculum material in order to analyse and self-evaluate the appropriateness of the new curriculum for better and more meaningful student learning of science.

In addition to the teachers' evaluations, it was considered important to investigate the effect of the new curriculum on the attitudes towards science of students of these teachers. This was achieved by use of attitudes to science questionnaire as pre- and post-test instruments.

The focuses above necessitated use of case study and action research as the two main research methods to obtain data for the present study. It was hoped that the study would provide insight into problems

encountered in implementing a constructivist Science for All curriculum in non-western countries. Beyond that, it was also anticipated that the study would provide evidence favouring the Science for All ideology of grounding the teaching and learning of school science in traditional children's real life experiences.

1.3 CONTEXT

This study was undertaken in Sierra Leone, the researcher's home country. Sierra Leone is a former British colony in West Africa. It has an area of 27,925 square miles and a population of about 3.5 million people. Historically, Sierra Leone was a leader in the implementation of Western education in Africa, mainly because of the arrival of the liberated black slaves from Nova Scotia in 1792. Fourah Bay College (now a constituent college of University of Sierra Leone) was founded in 1827 and became affiliated with Durham University in 1876. The system of education is still patterned along the British system including school calendar year. The structural pattern of primary, secondary and upper secondary education in terms of years is 7-5-2. Educational problems still abound, including:

1. A low level of literacy.
2. High failure and drop-out rates at both primary and secondary school levels.
3. The alienating nature of the curriculum.
4. The high cost of education.
5. Inadequate physical facilities.
6. High pupil to teacher ratios.

(Clarke, 1969)

Science is one of the core courses in the secondary school curriculum. At the junior secondary school level (Forms 1 and 2), the course is known as General Science and it is taught in isolation as specific branches of the three basic sciences - Biology, Chemistry and Physics. That is, the general science biology component is taught during the first term, the chemistry in the second term, and the physics component in the third term. General Science at the junior secondary school level is compulsory to all students in all schools. There is no centrally-controlled curriculum at this level (the situation is under review). Individual schools draw up topics which constitute general science syllabuses in their respective schools.

At the senior secondary school level (Forms 4 and 5), science is taught as pure sciences of Biology, Chemistry and Physics to students with career interests in science. For non-science students, Biology is studied as a compulsory subject up to Form 5. Alternatively, students in schools handicapped by lack of qualified teachers and laboratory facilities offer Health or General Science up to the Fifth Form. The curriculum for the sciences at the senior secondary school level is given in the teaching syllabuses outlined by the West African Examination Council (W.A.E.C.). The W.A.E.C. is the central examining body for the five English speaking West African countries of Nigeria, Ghana, Liberia, Sierra Leone and The Gambia. The council conducts the selective entrance examination at the end of seven years primary education, as well as the ordinary and advanced school certificate examinations at the completion of Fifth and Sixth Form education respectively.

The placement of Form 3 in the secondary school strata is problematic. Even though Form 3 is part of the junior secondary school level, examination pressures have made all schools start preparing students for the school certificate examination at that level instead of the official Fourth Form. Consequently, the three core sciences of Biology, Chemistry and Physics are introduced to all students at the Third Form level and these are taught as separate subjects by different teachers.

1.4 OVERVIEW OF THE STUDY

The remainder of this report comprises eight chapters. Chapter 2 provides a review of the research literature on the effects of cultural practices on science education, as well as on new directions in science education in non-Western countries. Chapter 3 continues the review of the research literature, focusing on the nature of science and the constructivist view of learning science.

Details of the research design and methodology are contained in Chapter 4.

Results of the research are reported over four chapters. Chapters 5 and 6 report results on students' attitudes to science, and case

studies of science teachers' perceptions of the junior secondary school science programme.

Chapter 7 describes the development and trialling of the constructivist Science for All curriculum by the science teachers. Results of these teachers' interactions with the new curriculum are contained in Chapter 8.

The report concludes with Chapter 9 which provides a summary of the main research findings, together with discussion of some major implications of the study and recommendations for future research.

CHAPTER 2: LITERATURE REVIEW OF EFFECTS OF CULTURAL PRACTICES ON SCIENCE EDUCATION IN NON- WESTERNISED SOCIETIES

Claims that school science programmes in many third world African and Asian countries lack cultural significance are frequently found in articles in science education journals. Unfortunately, such articles do not always sufficiently discuss the nature of those traditional cultural practices that are at variance with orthodox western scientific cultures. Indeed, traditional values conflict with the common view in western societies that a special strength of formal science is its ability to change or create new knowledge.

This chapter highlights some of those traditional cultural practices, especially African, (beliefs, norms and values), as well as the knowledge systems and thought styles which are in conflict with the western cultural practices through which science has evolved. Implications of these differences for the teaching and learning of science in non-westernised societies are discussed. Also considered is the rationale for science curriculum movements such as the Science for All curriculum movement which aim at making school science culturally relevant to the majority of the students. The chapter closes with a discussion on some of the unresolved questions challenging the Science for All ideology.

2.1 TRADITIONAL CULTURAL PRACTICES

2.1.1 A Definition of Culture and Cultural Practices

Samovar, Porter and Jain (1981) describe culture as the basis of the structure, stability, and security that both individuals and a society must possess if they are to maintain themselves. It is a medium that provides this foundation because it is dynamic and develops along the lines of self and societal survival. Culture is also the means of reproducing and training the individuals who comprise the society.

Culture is not an accidental collection of customs and habits. It is transmitted from generation to generation in the form of hidden

curricula, even if it is not taught in formal school education. Cultural factors help to shape individuals' behaviour, their expectations and their reactions to new experiences. Hence, the fact that people may well view their everyday life from the perspective of their traditional indigenous culture in African countries for example, justifies calls for cultural consideration in science education. As it has evolved in western culture, science carries beliefs, norms and values different from those of traditional indigenous cultures.

The phrase traditional cultural practices applies to those beliefs, norms and values which many black Africans employ to make sense of their world. Even though Africa is a vast continent, there is a remarkable similarity in the traditional practices of the diverse people of sub-Sahara black Africa (Driver, 1979). Furthermore, because about 85 percent of African children grow up in rural environment (Coombs and Ahmed, 1974), the generalisations made in the following section might apply to the majority of students in African countries.

To understand traditional peoples' view of themselves in African terms, as well as the nature of their thinking systems, a brief account of their beliefs, norms and values is given in the following sections.

2.1.2 Beliefs

Beliefs are propositions accepted as true, whether or not they are essentially verifiable. They are accepted on the basis of historical or cultural evolution. Beliefs are viewed as underlying support for behaviour. People of all cultures support their actions by elaborate systems of beliefs.

The belief system of African people includes shared knowledge, myths, legends and superstitions which provide a means of transmitting important features of social life and culture (Josiah, 1988). The system is centred on religion and the concept of the supernatural. The supernatural comprises three broad strands: belief in the supernatural, veneration for ancestors, and belief in natural divinities. These beliefs provide practical guidelines for

traditional peoples' behaviour, and to some degree determine their reactions to modern experiences.

2.1.3 Norms

Another influence on behaviour is that exerted by cultural norms. Cultural norms specify standard rules which dictate acceptable or appropriate behaviour, as opposed to unacceptable or inappropriate behaviour, in particular situations. Josiah (1988) summarized the following as some of the norms still upheld by many traditional Africans:

1. Respect for the dead (since they believe the dead survive in spirit).
2. Respect for age (elders are the main repository of traditional lores and geneological information; they are also the link between the ancestors and descendants in the family).
3. Respect for people in authority (leadership is the most important feature of the culture).
4. Pride in upholding one's dignity and that of the family (by respecting the dictates of the tradition).
5. Holding of property by group (land, house, etc).
6. Preparation of the young for adulthood (through initiation into secret societies. The secret societies give continuity to the culture and a sense of unity of the people).
7. Dominance of men in decision making.
8. Division of sex roles (men are externally occupied and women are managers of the home).

2.1.4 Values

Josiah (1988) describes a value as a particularly important belief shared by members of a society covering what ought to be or what is good or desirable. Values are not just preferences, but preferences which are felt and/or considered to be justified. Values channel motivation.

Traditional societies accord high values to etiquette associated with the form and nature of interpersonal relations. A person is regarded

as good if that person treats other people with respect and speaks well of them and to them. Such treatment embraces observance of traditional requirements of etiquette in which politeness and kindness are essential ingredients.

The young are taught to value courtesy and generosity, self control, respect for others, obedience to elders and observance of communal law. These values are taught through proverbs, stories, legends, riddles and oral commands.

The three attributes - beliefs, norms and values - combine to project the life style of a traditional person which is quite different from that of a western scientifically cultured person. Figures 2.1 through 2.3 are modified versions of Logan and O'Hearn (1982), and contrast the lifestyles of people in traditional and western societies.

	Type of Society	
	Traditional	Western Scientific
<u>Desired Traits</u>	Obedience, responsibility	Independence, self-reliance, achievement
<u>Economic Role</u>	Production (chores)	Preparation for future production (schooling)
<u>Purpose</u>	To carry on	To prepare for new life
<u>Education/Learning</u>	Through work, participation	Through preparatory training (schooling)
<u>Social Orientation</u>	Offering to others	Doing for self
<u>Children's Image</u>	Small adults	Future adults
<u>Shared Parent-Child Activities</u>	Work	Work plus "Children's Hour"

FIGURE 2.1 : Comparison of Life-styles of Traditional and Western Children

	Type of Society	
	Traditional	Western Scientific
<u>Time Orientation</u>	Toward tradition, past continuity	Toward future
<u>Life Space</u>	Circumscribed	Linear
<u>Guidance</u>	From elders	From peers and teachers (first type of experts)
<u>Locus of Wisdom</u>	Elders and tradition	Adults and experts
<u>Relationships</u>	Vertical	Horizontal
<u>Life Focus</u>	Group, family	Individual
<u>Feelings</u>	Group-regulated	Delay satisfaction
<u>Purpose</u>	"Be" Get along	"Do" Get ahead
<u>Economic Orientation</u>	Subsistence Cycle	Production/supply investment/thrift
<u>Jobs</u>	Already there; necessary to survive	To be made; necessary to advancement
<u>Meaning</u>	Carry on Tradition	Prepare for future
<u>Values</u>	Harmony vs. fatalism	Optimism vs. fear of failure
<u>Identity</u>	From continuity and place in group	From one's future role

FIGURE 2.2 : Comparison of Life-styles of Traditional and Western Adults

2.1.5 Traditional Knowledge System

Apart from identifying these major differences in life-styles, the above analyses suggest conflicts in understandings brought about by differences in the knowledge systems and the thought style of traditional and scientific cultures.

According to Josiah (1988), the knowledge system includes knowledge of others (largely believed or imagined), common sense knowledge, working knowledge (which may be technical, scientific or political), and perceptual knowledge of the external world.

In traditional African societies, knowledge is not so much 'what is, is right', as 'what has been, is right' (Josiah, 1988). Consequently, what is known about nature is passed from generation to generation and its source is in authority, rather than in observation and creativity. What is not known is destined never to be known. This way, knowledge is largely unproductive and there seems to be little or no need to transfer it to new situations (Gay and Cole, 1967).

Inculcation of traditional knowledge is through informal systems of education mainly by imitation and through initiation into secret societies. Children learn to do what their parents, the village or the tribe wants them to learn. Knowledge gained this way is said to be of high value and serves to preserve the community and as a support for the prestige of the elders. The disadvantage with this outlook towards knowledge is that the pragmatic and the innovative are subordinated to traditional values. Whatever is being done in the community is done with a view to preserving the society as it was founded. For this reason, the innovator is frowned upon, and independence is stifled.

2.1.6 Traditional Thought Style

The contrasting thought styles of people in traditional and scientifically cultured societies are listed in Figure 2.3.

	Type of Society	
	Traditional	Western Scientific
<u>Education Style</u>	Training via participation	Skills training
<u>Thinking Style</u>	Pre-ordained, repetitive	Systematic, Before-After, (Analytic)
<u>Intellectual</u>	"We"	"I"(Subject)
<u>Perspective</u>		
<u>Intellectual Attitude</u>	Acceptance of circumstances	"How does that work? (Event-Event/Cause-Effect over time)
<u>Causality</u>	"Cosmic" Formal & final cause (God(s))	Efficient and material cause
<u>Problem-Solving Technique</u>	Application of traditional techniques	Seeking new solutions

FIGURE 2.3 : Comparison of Thought-styles of Traditional and Western People

Horton (1971) argues that the theoretical models of traditional African religious thought are products of developmental processes comparable to those that have been responsible for the emergence of science in western culture. However, there are important differences between traditional and scientific thoughts, the key features of which he summarized as follows:

In traditional cultures there is no developed awareness of alternatives to the established body of theoretical beliefs, whereas in scientifically oriented cultures, such an awareness is highly developed (p.230).

Hence, traditional thought styles are said to be 'closed', unlike scientific thoughts which are 'open'. Ingle and Turner (1981, p.364) identify the following six areas relevant to science education which are examples of 'closed' thinking:

1. *Attitudes towards the prediction of events:* The traditional, like the scientific rational thinker, is vitally concerned with predicting events. But his/her attitude in the event of the repeated failure of a prediction is markedly different. The traditional thinker will invariably respond by 'excusing' each failure, while the rational thinker will eventually respond by attacking or modifying the theory.
2. *Attitudes towards cause and effect:* The traditional thinker tends to resort to 'converging causal sequencing'. This shows itself particularly in his/her attitude to divination, where an illness is linked jointly to a number of causes. If action is taken to get rid of an illness by dealing with one of the causes, and that action fails, it can always be said that another cause was a complicating factor. No matter how many failures there may be, the theory remains protected and does not need to be discarded.
3. *Attitudes towards experiment:* Scientific thinkers will take every opportunity of putting theories to the test of experiment, if necessary testing them to destruction. Traditional thinkers, on the other hand, are often content to wait for events to come along and show whether the theory is sound.
4. *Attitudes towards the confession of ignorance:* Traditional thinkers are extremely reluctant to confess ignorance about the answer to any questions, whether it be the outbreak of a disease or the failure of a crop.
5. *Attitudes towards coincidence, chance and probability:* Such concepts are poorly developed in the traditional thinker. If a rotten branch falls off a tree and kills a man walking underneath it, a definite explanation of the calamity is invariably sought. The idea of it being due purely to chance is unthinkable.
6. *Attitudes towards time:* The traditional thinker will tend to see things as having been better in the past - in some sense he will view the world as 'running down'. Closely related to this is the common justification for so much thought and action: 'that is what the old-time people told us'.

The 'closed' nature of traditional thought systems is said to be responsible for traditional peoples' attitudes to change. For example, traditional people seem to be unconcerned about contradictions. For them each society or culture has its own ways and the fact that they differ is not surprising. What affects traditional peoples' outlook on the teaching and learning of school science will now be considered.

2.2 EFFECTS OF CULTURAL PRACTICES ON SCIENCE EDUCATION IN NON-WESTERNISED SOCIETIES

The effects of cultural practices on the teaching and learning of science in non-westernised countries have been reported by researchers such as Wilson (1981) and Davey (1972). In the following sections, the bipolar world views of traditional students emerging as a consequence of their interaction with school science, is discussed. How the pedagogical assumptions implicit in the traditional culture affects the teaching and learning of school science is also highlighted.

2.2.1 The Bipolar World Views of Traditional Students of School Science

As a result of the disparity between traditional and scientific cultures, the learning of science at school has often resulted in traditional children formulating two world views, both independent of the other. Dart and Pradham (1967), in a discussion on the cross-cultural teaching of science, sought information on how 9-14 year old traditional school children accounted for phenomena such as earthquakes. They reported obtaining two different types of explanations - mythological and scientific - from members of the same group, and sometimes from a single individual.

An example of a mythological response was: "The earth is supported on the back of a fish. When the fish grows tired it shifts its weight and this shakes the earth". A scientific explanation on the other hand was: "There is fire at the centre of the earth. It seeks to

escape and sometimes cracks the earth, causing earthquakes". Cockright(1974) supported this finding by reporting that Kpa-Mende school children in Sierra Leone offered similar explanations of natural phenomena related to home information in spite of scientific explanations given to them at school.

This type of dualism not only exists among traditional students. There is evidence of different world views held by western students too. Solomon (1983) reported that even academically successful western students can cross easily between two very dissimilar, but coexisting, spheres or domains of knowledge which she calls life-world knowledge and scientific knowledge. But while the two world views do not prevent the western student from adopting scientific attitudes, the converse is the case for the traditional student. Traditional students tend to cling more to their life-world knowledge than to the scientific one. The overall effect has been the failure of school science to create a meaningful impact on the lifestyles of traditional people. Specific examples of the tendency of traditional students to remain entangled in their life-world knowledge are provided below.

Because school science is learned in a context quite divorced from their lives, (Sawyer, 1979) claimed that traditional students tend to drop science when they leave school and enter their home environment. Classic examples can be found in the experiences of Sierra Leonean children who studied science both at the primary and secondary school levels. On returning to their villages these children continued to drink untreated water collected from streams because of traditional beliefs that running streams are purified. School science knowledge of properties of pure water or ways of purifying water for drinking cannot challenge the mythical conviction that angels purify running streams every Friday. Similarly, knowledge of school science could not help these students to understand the mechanism of a swinging bridge as an application of forces in action. Instead the mechanism was perceived as a by-product of witchcraft. Neither can many of these students tell their heights off hand. Traditional beliefs that one does not measure the height of a living person inhibits students from voluntarily measuring their own heights.

The above examples illustrate what may be termed the reversal effect of science education on traditional students. No matter how much

science is studied at school by these students, at the end of the educational process it is the traditional beliefs and values that tend to flourish. The next section describes how the traditional outlook on ways of acquiring new knowledge conflicts with school science pedagogy.

2.2.2 Pedagogical Differences: Traditional Versus Scientific Enquiry/Problem Solving Methods

Another implication of the disparity between traditional practices and science education lies in pedagogical assumptions implicit in each of the two kinds of culture. Both science and traditional cultures have different views on ways of acquiring new knowledge. The disparity between traditional method, and the scientific enquiry and problem solving methods, is illustrated below.

Wilson (1981) has argued that enquiry-based styles of teaching, in which pupils are encouraged to question teachers' assertions and to test the validity of statements for themselves, are not successful in traditional societies. In traditional societies it is conformity rather than ingenuity that is of highest social value. Furthermore, knowledge is seen as static, to be passed from generation to generation as approved by elders (Dart, 1972, Davey, 1972). The following example indicates how this same attribute of conformity dampens problem solving aptitudes in traditional students.

Writing about his experience of teaching science in Nepal, Trowbridge (1974) reported that, despite differences in religious practices, children exhibit a similar attitude to solving problems which is a reflection of their adult society. According to him:

Unlike an American child who will see the situation in terms of dealing with it and coming up with solutions, a Nepali child has been brought up to accept a situation by making reference to some traditional problem. Instead of inventing a solution, he/she will be remembering a solution (Trowbridge 1974, p.26).

Similarly, problem solving for Kpelle children in Liberia consists of the transmission of solutions from generation to generation. The primary goals of education for the Kpelle people are maintenance of the past, conformity and learning through imitation of the elders (Gay and Cole, 1967).

This approach to problem solving is common to most African traditional societies in Africa. In these societies, teaching students to think for themselves is opposed to traditional thought. Consequently, the type of method of teaching science that has flourished is one that relies heavily on rote memory, the teachers' main task being the conveyance of a body of knowledge in the form of sets of facts to their students.

The above analysis leads to the conclusion that school science represents knowledge imposed on traditional students who come to school with a wealth of beliefs about the world. These traditional beliefs, which make sense of the world to the traditional students, often conflict with what is taught in science lessons. Hence, for the majority of these students the meaningless information given to them in science lessons is shelved only to be used for the purposes of passing school examinations. Once outside school, it is the traditional knowledge which makes sense of their world and to which they adhere.

Even the very few who successfully play the school game of memorizing the learned facts and reproducing them in examinations end up accumulating only the 'know why' understanding of natural phenomena. These seemingly knowledgeable people really lack the 'know how' because they are brought up to believe that it is someone else's business to turn that understanding into practical application (Urevbu, 1984). The sort of skills needed by the majority of the students who will never go beyond secondary education are glossed over. Hence, Fensham's (1985) claim holds true for many African countries that the present school curriculum has not achieved an effective science education in schools for the 80 percent who will probably not continue with any formal education in science after completing school.

To improve the situation in these countries calls for a new rationale in science education. Instead of superimposing values that are hardly ever assimilated by traditional children, science education might best serve as a medium for bridging the gap between traditional and scientific outlooks on nature and knowledge.

Non-western societies have lost the freedom to exclude science as a culture from their own culture, because science and technology have become widespread 'cultures' in the world (Ogawa, 1986). The challenge, then, is to formulate ways of merging the two cultures to produce science curricula that are relevant to the majority of traditional students and societies at large.

In the 1980s the need to make science more relevant to the majority of learners in both western and traditional societies has given rise to calls for a new direction in science education. Efforts by non-western societies to develop science curricula that are sympathetic to their cultures and their immediate needs will be described in the following section.

2.3 NEW DIRECTIONS IN SCIENCE EDUCATION IN NON-WESTERN COUNTRIES

Targeting science education towards the greater school population has mushroomed a whole liturgy of terms such as Science Education for Society, Science Education for Life, Science and Technology Education for Development and others (Knamiller, 1984). But the overriding slogan for all of these is Science for All.

2.3.1 Science for All

As the name implies, the main aim of Science for All is to provide the majority of students with scientific competencies, knowledge and skills appropriate to their immediate needs. Important features of the Science for All ideology are centred around considerations which Fensham (1985, p.426) identifies as follows:

1. It should involve content that has immediate and obvious personal and social relevance to the learners. That is, it ought to begin as an extension of what the learners already know from their experience prior to schooling.
2. Its learning objectives (practical skills and knowledge) should have criteria of achievement that most learners can realize at some level.
3. Its broad themes, topics or sections should constantly be visible to elucidate the component parts of the learning.

4. Its pedagogy should exploit the demonstration and practical modes that are inherent to much science, and also in the cultural learning that occurs prior to and outside school.
5. The learning of practical and cognitive skills should flow naturally from the relevant and meaningful nature of the science topics, rather than be themselves a primary focus of the learning.
6. Its assessment should recognize both the prior knowledge that learners have of scientific phenomena and their subsequent achievements in all the various sorts of criteria for learning that make up the curriculum.

The factors above provide an appropriate framework for the science/traditional cultural interface that is currently associated by many as the new focus for school science in non western societies. The framework takes into account students' pre-school and post-school dispositions which are often ignored in existing science curricula, and prompted the present researcher to design a science curriculum model for non-western countries grounded in the Science for All ideology. Other curriculum efforts to implement the Science for All in non-western countries will now be discussed.

2.3.2 Science Curriculum Trends in Non-Western Countries

Two aspects of curriculum effort in non-western countries are worthy of mention. These are policy and implementation. A brief account of each of these, together with foreseeable problems associated with the Science for All ideas, is presented in the following sections.

* Policy

To provide the majority of students with the type of knowledge and skills the Science for All advocates, many third world countries have formed policies that cater for the development of indigenous and culturally based science curriculum programmes. The Foundation para la Aplicacion Enseñanza de las Ciencias in Colombia has taken a holistic, community specific approach which states that:

Education for development must start with identifying the characteristics needed to develop human potential for solving local community problems. Knowledge and skills are then selected for curricula which reflects local needs (Knamiller, 1984, p.67).

Asian countries have developed a unanimity in science education policies that claim:

Education in science and technology should not alienate a learner from cultural heritages and values; that curricula must be adapted to cultural conditions and practices and must be appropriate and in harmony with cultural concepts and values and results in better quality of life (Seng, 1979).

Describing future directions for science education in Africa, Ogunniyi (1986) suggested that emphasis should be on topics relating to mechanized farming; control of malaria and other tropical diseases; provision of good drinkable water; and the production of food. He described these as societal-needs topics. Apart from regional or national policies, there have also been contributions from researchers recommending policies that would optimize the goals of Science for All. Thus Kelly (1980) recommended a shift that would bring school science towards community needs, a process he described as an issue-based approach. The assumption underlying his suggestion is that children who study issue-based science will be better equipped to make decisions and participate in community action on issues relevant to their lives when they leave school. Another possibility, according to Knamiller (1984), is to exploit the potential of local indigenous technologies for teaching science content. The extent to which some of these policies have been implemented is outlined below.

* Implementation

New science curriculum policies have been tried in some third world countries. The following developments are reported in a report of a U.N.E.S.C.O. - A.P.E.I.D. Southeast Asia and Pacific countries conference on more functional science education. In Thailand, the content - oriented training of science teachers is being replaced by a Competence-Based Teacher Education (C.B.T.E.) programme. C.B.T.E. emphasizes the performance of the teacher trainees on the basis of their ability to promote desirable learning and behavioural outcomes of their students. In the Philippines, curriculum development has been decentralized in one or two regions with the aim of encouraging science teachers to prepare some modules specific to regional and

community needs. Other implementation strategies have involved extra curricula activities that have linked school science to community problems.

As a means of popularizing science, Bangladesh and Zambia have initiated science club and science fair movements (Knamiller, 1984). In India there have been curriculum efforts to orientate teachers to the principle of work experience and the development of necessary skills for utilizing techniques which improve life conditions. The scheme includes work on topics such as water filters; new varieties of crops and fertilizers; and the promotion of the habit of scientific thinking with the aim of students gradually introducing them into their communities (Ahmed, 1979). The students are also expected to tap a local fund of traditional knowledge in medicine, weather, beliefs and folklores with the aim that "these elements can then be subjected to the test of scientific analysis to perhaps discover the kernel of truth in this neglected store of knowledge" (Ahmed, 1979)

Knamiller (1984) reported how Vielfaure (1980) encouraged rural Zambian students, who lacked the equipment and laboratory facilities of their urban counterparts, to discover what scientific principles are involved in things done by their ancestors and still being done. Some of the projects developed were Bellow Making, African Medicine and Traditional Home Building. The results of these projects constituted part of the series of units called Third World Science co-ordinated by Professor Iolo Williams of University College, North Wales. In a study of the environmental perceptions held by rural Ghanian children, Knamiller (1983) identified a range of issue-based topics from food crop pests to small scale industries, which arise from children's knowledge and experience of their environment. The Zimbabwe Environmental Science programme for primary schools has incorporated local issues into the formal science syllabus.

The above examples depict curriculum efforts aimed at making school science more meaningful to the majority of the learners in non western countries. The next section describes some of the unresolved questions that still surround those curriculum efforts.

* The Dilemma of Relevance in Science for All

Discussion on the dilemma of relevance recapitulates problems some critics foresee in the Science for All ideas. The arguments are centred around the theme that relevance in science education has different meaning for different parties involved in the educational process. The following discussion illustrates how the perception of relevance by outsiders (Governments, policy makers, curriculum developers) differs from that of the insiders (consumers - parents and students). It also addresses the theoretical debates on what counts as relevant knowledge in science.

As appealing as new science innovations may appear in principle, the fusion of Science for All orientated curricula with the existing school system faces hurdles. For example, there is still a large gap between policy and implementation (Al-Hidabi, 1982; Igboaka, 1981; U.N.E.S.C.O.-A.P.E.I.D., 1981) which springs from the fact that what is regarded as relevant knowledge or skill in the Science for All scheme is still an ambiguous notion. Many policy makers in governments of third world countries believe that, for the vast majority of people in less developed countries, the growth of technological capability must be equated with the development of indigenous science that aims at self-reliance. The insiders (that is, the consumer - students and parents) hold quite a different perception as noted in the following examples.

Fafuwa (1967) points out that African governments usually see industrialization as the key to national economic improvement and aim to produce people trained in the physical sciences and technology. In contrast, most parents and pupils view educational relevance as an indirect path to improving life. They see formal education as the one possible escape route from a life of rural drudgery (Emina, 1973). For this reason, in many third world countries, Mathematics, Physics and Chemistry have become high status subjects in schools, while agriculture is despised and shunned (Chaplin, 1961).

Consequently, insiders do not take seriously those technologically-orientated courses such as Home Economics, Agricultural Science and Craft which have been included in the curriculum to provide all children with knowledge that they can apply at home. The reason is

that these subjects hold little status when students apply for university entrance. One glaring example is the status of Agricultural Science in the secondary school curriculum in Sierra Leone. To gain admission to the Faculty of Agriculture, the competition for the limited space in the early 1980s was so keen that the minimal entry requirement was five 'O' level passes, including an aggregate score of C in Chemistry, Biology and Physics. Agricultural science was not considered as one of the core sciences.

To further illustrate how consumers' perception of relevance can conflict with those of outsiders, the case of the Bunumbu Primary Teachers' College in Sierra Leone is highlighted. The College is part of a U.N.E.S.C.O. project that aims at training school teachers for community development as well as classroom teaching. In 1979, the principal of that institution insisted that, first and foremost, his teachers must be able to give rural children an equal competitive chance to pass the national school leaving examination for entrance to secondary schools (Knamiller, 1984). The principal's stand demonstrates societal expectations that place high premium on paper qualifications.

Conflicts of this nature exist in other third world countries. In 1983, an 18 year old black Zimbabwean school graduate, commenting on the national discussion about replacing the Cambridge Overseas Ordinary and Advanced level examinations with one of its own, emphatically argued against it. A national examination, he reckoned, meant that Zimbabweans would be much less likely to gain admission to foreign universities. The disparities between insiders' and outsiders' perceptions of the relevance of education are so different that the director of the Zimbabwe Science Project for the post independence rural secondary school observed that the development of relevant science is not a realistic project at the moment (Knamiller, 1984).

Another criticism surrounding the relevance ideology arose out of theoretical arguments on what kind of knowledge should learners acquire from studying Science for All. Fensham (1986) argued for an approach that focuses on learning "about and from science" (p. 14) as a way of providing science for the "all" who are outside the discipline. To effect this change, he argued that inductive or

elitist science education must be confined to an upper level of schooling while the Science for All should emphasize topics such as Senses and Measurement, Human Body, Health, Nutrition and Sanitation, Food, Population, Pollution and Uses of Energy.

Munby and Russell (1987) claimed that Fensham's suggestion will boil down to a science education programme that advocates the transmission of scientific information without the intellectual context of science. In that respect, they argued that Fensham's version of Science for All may be interpreted as "True Information for All". This is more likely to be the situation in many third world countries where there are no tertiary institutions that prepare teachers to teach core content curricula. In Sierra Leone, for instance, many students who study physical sciences at tertiary level are likely to have studied Biology beyond the fifth form. The majority who study Biology on the other hand have no formal learning in Physics beyond the third form.

For this reason, the core topic approach for the teaching and learning of science may not be the best alternative, especially in those countries where there are no competent trained teachers to handle core content syllabuses. Science, like most other disciplines, has its own distinctive truth criteria, logical structure and methodology (Lawton, 1975). These qualities, are likely to be downplayed in core curricula taught by ill-trained science teachers.

Nor is the notion of having two kinds of science curricula, one for the science-bound student and the other for the majority all, a viable option. Provision of different science programmes for different classes of students is as controversial as the notion of relevance itself. It re-opens debate on the distribution of knowledge which is another unresolved area in curriculum design (see Bernstein, 1971). The question of who receives what type of science education, and for what purpose, has no unilateral answers.

2.4 SUMMARY AND CONCLUSION

The question of relevance for science education remains unresolved. However, there is a consensus on making learning of school science more meaningful and relevant to the majority of the learners as called for by the Science for All movement. How the Science for All ideology could be integrated into existing school curricula requires further researching.

This present study was undertaken in response to the challenge of investigating ways of incorporating ideas of Science for All into existing school curricula in a non-western society (Sierra Leone). The study entailed working with local science teachers who understood the real-world view of Sierra Leonean students, and who could make judgements about the type of science programme that was relevant for those students.

Case study work led to an action research programme in which teachers worked collaboratively with the researcher to develop general science curriculum for junior secondary school students that was grounded in the Science for All ideology. Teaching units were developed for Form 1 and 2 students on two topics: Measurement and Force. The theoretical model for this curriculum is discussed in the next chapter following a review of the philosophical and psychological underpinnings that informed the curriculum model.

**CHAPTER 3: LITERATURE REVIEW OF THE NATURE OF SCIENCE
AND THE CONSTRUCTIVIST VIEW ON LEARNING
SCIENCE AND CURRICULUM DEVELOPMENT**

Recent debates in the philosophy of science and the psychology of learning suggest ideas that support the Science for All approach of basing the teaching and learning of school science on learners' real world experiences. This chapter reviews some of those ideas and the implications they have for science education in non- western countries. The chapter also describes a proposed junior secondary school general science curriculum which integrates the emerging theoretical ideas with those of Science for All. The conclusion indicates the areas of study that emerged as important for the present research.

3.1 PHILOSOPHICAL INSIGHT INTO THE NATURE OF SCIENCE

It can be argued that the view of science conveyed in most school science curricula is very different from current theories in the philosophy of science. Hodson (1988) attributes the failure in appreciation and applicability of the acquired scientific knowledge or skills to two causes:

1. The degree of confusion in philosophical stance implicit in many contemporary science curricula.
2. Teachers' own inadequate views about the nature of science.

On the question of confusion in philosophical stance, Hodson explains that the period of curriculum innovations of the 1960s coincided with equally rapid changes in the philosophy of science, characterised by the work of Karl Popper, Thomas Kuhn, Imre Lakatos and others. But since curriculum developers were uninformed by philosophical developments, the views of science methodology contained within the curriculum proposals were confused, frequently contradictory, and at times based on dubious philosophies of science (Martin, 1979). To

illustrate the degree of confusion in philosophical assumptions in most science curricula, some analyses of typical images of school science are discussed in the following sections.

3.1.1 Images of School Science

Hempel (1966) described the image of school science as a narrow inductivist concept of scientific inquiry. Cawthron and Rowell (1978) described it as an empiricist - inductivist approach which in their view:

is basically founded in the conception of scientific method as described by Bacon : a well defined, quasi-mechanical process consisting of a number of characteristics stages:

- (1) *observation and experiment;*
 - (2) *inductive generalization;*
 - (3) *hypothesis;*
 - (4) *attempted verification;*
 - (5) *proof or disproof;*
 - (6) *objective knowledge*
- (Cawthron and Rowell, 1978; p.33)*

Smoliez and Nunan (1975, p.106) identify four implicit assumptions which they call the ideological pivots of the image of science:

1. The anthropocentric view of the universe (with humans as conquerors and controllers of nature through science).
2. The principle of quantification and demystification of the world (the belief that whatever exists in nature must be quantifiable).
3. The positivistic faith in progress of science (the continuous advance of the technology through application of the scientific method).
4. The analytic ideal (that the whole is best understood by studying the components).

In a parallel analysis of school science, Nadeau and Desautels (1984) state that it propagates five myths:

1. Naive realism (that scientific knowledge is the reflection of things as they actually are).
2. Pedagogical neutralization (that we see things as they really are).

3. Blissful empiricism (that all scientific knowledge derives directly and exclusively from observation of phenomena and the view that the human mind is a tabula rasa on which knowledge can be recorded item by item).
4. Pedagogic attenuation (that to observe usually means to look at alternatively so as to note as many details as possible).
5. Credulous experimentation (that experimentation makes possible conclusive verification of hypotheses).

A number of these descriptions can be summarized by the observations of Hodson (1985: p.27) that:

1. Science gives access to factual truths about the world through detached observation.
2. Scientific knowledge is derived directly from the observation of phenomena.
3. Science rationally tests its propositions by means of objective and reliable experimental procedures.
4. Science is neutral activity untainted by socio-historical and economic factors producing value - free knowledge.

These factors project an image of science as being objective, unbiased and possessing a critical and impeccable method (Cawthron and Rowell, 1978). This image is portrayed through the schools' hidden curriculum by a process Eastman (1969) called scientism.

3.1.2 Scientism

Eastman (1969) described scientism as an activity based on the ontological thesis which presumes the existence of real, isolated entities standing apart from human perception and conception, and waiting to be uncovered by the scientists. Expounding how scientism is propagated through the hidden curriculum, Duschl (1988) reports that research on the content of textbooks, on teachers' attitudes about the nature of scientific inquiry and on verbal interaction behaviours in science classrooms demonstrate a view in which scientific knowledge is prescribed as absolute truth in its final form.

For example, from a content analysis performed on 57 High School lessons, Gordon (1984) noted that typical of most science lessons is

the tendency for teachers to move towards conclusions. That is, no matter how broad the topic may appear at the start, there is always an enveloping sense of the lesson being moved along in a definite direction, towards some pre-ordained conclusion, suggesting to pupils that they are dealing with truth. In other instances, given teachers appeared to know the right answers to questions posed in science lessons, and pupils' answers to these questions had to fall in "Yes" or "No" dichotomies with no mid-way alternatives. This is also suggestive of a final nature for scientific knowledge.

In summary, Nadeau and Desautels (1984) describe scientism as implying:

An attitude towards science that sees it not only as an activity involving special knowledge, because of its specific and time-tested method of solving problem, but as one with cognitive basis that is beyond question. Scientific activity is thus immune to criticism, because any criticism, to be considered scientifically valid, must itself be scientifically based (p.13).

However, all the assumptions on which scientism rests - that we can observe the external world directly and immediately, that induction can generate general laws, and so on - are now seen as being contestable on epistemological and logical grounds. It is now recognized that the Baconian account of science which is the main pillar of scientism does not fit science as it is actually practised. Science does not use exclusively the method of observation, experiment and induction. It is these differing views concerning the status of science that has awakened discussion on how the philosophy of science has relevance for science education. Of particular interest is the work of Popper and Kuhn.

3.1.3 Popper's and Kuhn's Contributions on Nature of Science

According to Popper (1959), science does not come from passive observations leading to the formulation of general laws about nature. Rather, science stems from the formulation of conjectures or tentative theories with which scientists try to understand nature. The crucial feature of scientific method, then, is that it does not seek to confirm scientific generalisations by collecting particular instances which confirm those generalisations. Instead, it actively seeks to

falsify and refute the conjectures or hypotheses, put up to explain natural phenomena. If the facts refute the conjectures or hypotheses they are discarded. Science, then, is the body of those conjectures or theories which have so far resisted refutation or falsification (Charlesworth, 1982).

Supportive evidence does not necessarily authenticate the validity of a theory. It merely means that the theory has withstood particular tests, and must be exposed to progressively more stringent tests until such time as it is falsified. It is this openness to refutation and correction, and the rejection of any dogmatic or closed view of knowledge, that are the essential characteristics of science for Popper. From his perspective scientific knowledge is forever provisional.

Another contributor to modern philosophy of science is Kuhn. Kuhn (1970) challenged Popper's assumptions that one can define science in terms of its method without looking at how science is actually practised. He introduced two further dimensions: the revolutionary nature of change in science; and the recognition that science is not simply a matter of theories confronting nature but communities of scientists are also involved. Kuhn's view of science and its progress is characterized by three terms: "normal science", "revolutionary science" and "paradigm".

Normal science constitutes the bulk of scientific work done, and is notable for the acceptance by its practitioner of a system of concepts, methods and assumptions, any or all of which Kuhn calls its "paradigm". The role of normal science is to fiercely strive to produce a better fit between the dominant theory and the real world. A serious mismatch between reigning paradigms and reality will cause a crisis leading to revolutionary science in which new paradigms replace older ones. This condition is suggestive of the relativistic nature of scientific knowledge.

Although Popper's and Kuhn's accounts of science have not gone unchallenged (Charlesworth, 1982), their contributions, together with those of their followers (Lakatos and Karl Mannheim in particular) have emerged with a view of science with some amount of consensus on many key points. Hodson (1986, pp. 216-217) lists the following

emerging views as those relevant to school science curricula:

1. Observations are dependent on our sometimes inadequate sense perceptions and, therefore may be unreliable and fallible.
2. Observations are theory dependent and theory often, though not always, precedes observation.
3. Science often utilises indirect observation which, in turn, depends on a theory of instrumentation.
4. Observations do not provide automatic access to secure factual knowledge; they must be interpreted in the light of current theoretical beliefs.
5. Concepts and theories are produced by creative acts of abstraction and invention. They do not arise directly from observation by a process of inductive generalisation.
6. Theories are often justified post hoc by experimental evidence, but for a theory to be accepted there must be (conceivable) supporting evidence.
7. Competing theories may give rise to non-identical observations when confronting the same phenomenon.
8. Scientific knowledge (observational data and theories) has only temporary status. Concepts and theories change and develop, some are discarded.
9. Induction is inadequate as a description of scientific method and so the discovery learning methods often employed by science teachers project a distorted image of science.

To translate these points into a framework that will assist the learning of science and promote a better understanding of the nature of science, Hodson (1986, p.217) identifies the following five major focuses of attention for the science teacher and curriculum designer:

1. Recognition that observation is unreliable and theory dependent.
2. Realisation that the techniques of scientific observation have to be learned.
3. Acknowledgement of the need to take account of children's existing conceptual frameworks, since they profoundly influence the observational work the children can undertake and their success in acquiring new ideas.
4. Reconsideration of the desirability of the discovery learning approach in the light of the dynamic relationship between observation and theory.
5. Rejection of the value-free image of science traditionally presented in the curriculum.

The above considerations have led to major shifts in science education such that it ceases to convey the 'bucket image' of science which conceives of human mind as:

A bucket which is originally empty, or more or less, and into this bucket material enters through our senses and accumulates and becomes digested (Gordon, 1984, p.372).

In contrast, it is now realised that observations which are made and are not made, the way they are made, and the terms in which they are recorded, are influenced by the theories that scientists hold (Philips, 1985). In other words, the human mind is never actually totally blank. Correspondingly, learning theories have emerged that lend support to this view. Details of these theories are discussed in the following section which addresses recent psychological developments that have relevance to science education.

3.2 PSYCHOLOGICAL THEORIES ON LEARNING

Since the turn of the century, educational psychology has initiated fundamental changes in the study of human learning (Wittrock, 1974). People like E.L. Thorndike, B.F. Skinner, R. Gagne, R. Atkinson and others have contributed to revolutionizing educational conceptions of learning, teaching, instructing, training and the transfer of learning.

During the 1970s, the influence of cognitive theorists such as Bruner, Piaget and Ausubel increased. This resulted in a paradigmatic shift towards the perception of knowledge as a psychological entity in the minds of individuals rather than as an objective entity in the real world. It is this outlook on knowledge and how it is acquired that is the underlying thesis of the constructivist theory of learning.

3.2.1 The Constructivist View of Learning Science

Central to this theory is the importance of meaning as constructed by individuals in their attempt to make sense of their world (Wittrock, 1974). In this context, learners' existing ideas are all important in

responding to and making sense of stimuli. New knowledge is acquired, not by the internalization of some outside given meaning, but by construction from within of appropriate representations and interpretations. Thus, the sense made of any event is seen to be dependent not only on the situation itself, but also on the individual's intents, beliefs, emotions and conceptualisations.

Although the origins of the constructivist tradition date back to the Greeks (Osborne and Wittrock, 1983), recently there has been a considerable surge of research interest in this field. Claxton's development of mini-theories using the work of George Kelly (1955) has profound implications for the learning of science. A brief account of Claxton's work which evolved around Kelly's theory will now be discussed.

3.2.2 Claxton's Mini-Theories

Claxton (1984) subscribes to Kelly's (1955) view that actions and intuitions of individuals arise out of personal theories about the world which govern descriptions and explanations each individual provides about the world. He called these personal theories "mini-theories".

Claxton argues that in learning about the world people develop mini-theories which apply to specific situations and help them to make predictions and decide on certain actions.

The theories may operate at a subconscious level of thinking. They need not be articulated and can be used in spontaneous and intuitive ways. For example, children quickly develop a theory about impulse when they jump down from trees. This happens intuitively when they bend their knees rather than landing with their legs straight. This increases the time of impact. A relationship between the amount of pain felt and the time it takes to complete the jumping exercise is subconsciously established. Similarly, the theory of projectile motion is unconsciously learnt and spontaneously applied in learning to catch heavy objects such as cricket balls and lighter objects such as tennis balls.

Language provides the means through which children are able to describe and explain things to others in term of mini-theories. Claxton argues that children, like scientists, change mini-theories when it is expedient to do so. In general, incorrect predictions or actions, or descriptions and explanations which are no longer useful lead to changes in mini-theories. Alternatively, reinforcement occurs when they lead to successful predictions, actions, descriptions and explanations.

Extending his concept of mini-theories to learning science, Claxton identifies three layers of science - "gut", "lay", and "school". Gut science is based on intuition and spontaneous reaction. Through trial and error gut science is acquired from direct experience rather than through language. Examples include: rubbing causes things to heat up and wear out, things need a push to get them going and heavy things fall fastest.

Lay Science is based in the form and content of the child's language, and on the accounts and images of experiences conveyed by the people the child interacts with, and also from the media. Examples of lay science are: astronauts are weightless in the space shuttle, oil reduces friction and hence reduces wear and space travel requires powerful engines at all times.

School Science is based on the symbolic and idealised world of the science classroom. It has a linguistic and mathematical super-structure of its own which Claxton describes as "fantasy". In this domain we hear of frictionless surfaces, weightless strings, uniform gravitational fields, point masses, ideal gases and so on.

Existence of the three clusters gut, lay and school science suggests the possibility of different groups of individuals having different kinds of knowledge, even about the same topic. Accordingly, Gilbert, Watts and Osborne (1985) delineated five loci of science knowledge which Kirkwood (1988,p.30) summarises as follows:

1. Scientists' science - meaning for words held by a consensus of the scientific community;
2. Curriculum science - a version of scientists' science selected by curriculum planners for syllabus or textbook

3. Teachers' science - the product of the interaction between curriculum science and the teacher.
4. Students' science - the product of the interaction of children's science and teacher's science in the classroom; and
5. Children's science - the meanings for science-related words held by children before formal school science.

Kirkwood further observes that the nature of knowledge residing in these different locations can be different in both quantity and quality. Research evidence now abounds indicating that students hold knowledge about science which are different from those believed by scientists (Driver and Erickson, 1983, Gilbert and Watts, 1983; Osborne and Freyberg, 1985). The differing students' conceptions have been called preconceptions (Ausubel, 1968), misconceptions (Helm, 1980), children's science (Gilbert, Osborne and Fensham, 1982).

Acknowledgement of the alternative conception theory raises a pedagogical proposition. It suggests that learning may involve changing a person's conception by either adding or modifying what already exists there. This view has been developed into a model of learning as conceptual change (Hewson, 1981; Shuell, 1987; Posner and Gertzog, 1982). A brief account of the conceptual change model of learning is given in the following section.

3.2.3 Learning as Conceptual Change

Conceptual change in learners can occur in different ways. Rumelhart and Norman (1978) suggest three ways in which cognitive structures may change: through accretion - the addition of new conceptions to existing structures; through tuning - involving small modification of existing structures; and through, restructuring of existing conceptions which may involve major changes.

Strike and Posner (1982) suggests that for a conceptual change to occur, there must be some dissatisfaction with the existing conception. The incoming conception must also appear intelligible, plausible and fruitful in offering new interpretations. A more detailed description of how conceptual understanding and science learning do take place is given by Pines and West (1986). To

summarize the discussion on the constructivist view and the conceptual change of learning, some salient points about learning are listed below.

3.2.4 Salient Points about Learning

The views of learning as derived from the constructivist tradition discussed so far have been summarized by Driver and Oldham, (1985; p.8) as follows:

1. *Individuals are purposive.* This assumption which is the nucleus of constructivism asserts that the locus of control of behaviour is with the individual. Rather than learning in a passive way by responding to the environment, the individual is seen as actively interacting with the environment to make sense of it.
2. *Knowledge is constructed by individuals through social interactions and experience with the physical environment.* We cannot check our knowledge against an external reality. Our only check is the extent to which our constructions fit our experience in coherent and consistent way.
3. *Individuals' knowledge and belief structures influence the meaning they construct in a given situation.* What is learned in a given situation depends on the learner's present knowledge structure and beliefs as on the characteristics of the learning environment.
4. *Constructing meaning is an active process.* To construct meaning in a situation involves active participation by the learner in making connections between aspects of that situation and the learner's prior knowledge. This is seen as taking place through a dynamic process in which a learner generates possible hypothetical meanings and check these for fits in the situation. The process for checking for fit may involve testing hypotheses against evidence available from sense experience and its coherence with the learner's knowledge structure.
5. *Understanding is not the same as believing.* It is possible to construct a meaning to generate a way of seeing something yet not believe it.
6. *Learning scientific ideas involves conceptual change.* This may simply require the extension of pupils' conceptions in order to interpret new phenomena or, alternatively, it may involve a more basic restructuring of ideas.

3.3 IMPLICATIONS OF THE PHILOSOPHICAL AND PSYCHOLOGICAL DEBATES FOR SCIENCE EDUCATION IN NON-WESTERN COUNTRIES.

The discussion on the nature of science and the constructivist view of learning science have identified the new insights that could have profound influences on the teaching and learning of science in traditional societies. The realisation that science is a human construct (that it is an activity of human beings interacting with one another in a structured community and it takes place within and depends upon the larger society and culture) invalidates earlier beliefs that science education is culture free (Morehouse, 1967; Ziman, 1969). That tradition, myth and legend form an important part of individuals' interpretation of their environment (Williams, 1982) justifies calls for culturally based science curricula in non western countries. Such curricula should advocate teaching and learning of science programmes in the context of the learner's real world.

The constructivist belief that the learner's prior knowledge is the *sine qua non* in constructing meaning (Pines and West, 1986) has pertinent implications about traditional students whose prior ideas mostly conflict with those learned in science lessons. To make the learning of school science more meaningful and relevant for these students requires a new curriculum emphasis in which the aims, contents and methods are centred around ways of merging prior ideas with incoming scientific ones. This proposition lends support to the notion of the traditional/scientific interface established out of sociological considerations in Chapter Two.

It is this recognition of students' prior ideas as a key factor in their learning of science at school that has re-activated interest in student-centred science education programmes. Alongside the student - centred perspective has emerged a constructivist view of curriculum development (Driver and Oldham, 1985; Bell, 1990).

This curriculum alternative incorporates criteria that take into account both students pre-school and out-of-school dispositions which have been identified as essential considerations in order to maximise the Science for All objectives. Such consideration influenced the present researcher to design a General Science curriculum for junior secondary schools in Sierra Leone patterned along the constructivist model. Details of this curriculum model are given below.

3.4 PROPOSED GENERAL SCIENCE CURRICULUM MODEL FOR JUNIOR SECONDARY SCHOOLS IN SIERRA LEONE

The General Science curriculum proposed by the present researcher for junior secondary schools in Sierra Leone was a modified version of Driver and Oldham's (1985) constructivist science curricula model (see FIGURE 3.1).

3.4.1 The Aims and Objectives of the Curriculum

The aims and objectives of the curriculum are as follows.

Aims

The general aims are to enhance the development of creative and scientific thinking in children, and to facilitate the development of their positive self-concepts and attitudes towards science and science learning. In addition learning science at school should prepare traditional children capable of challenging multivarious problems of poverty, famine and poor living standards in their societies.

Specific Objectives

Learning science at school should prepare pupils to:

1. Understand the why of things and how it affects living.
2. Recognize scientific knowledge as human construct to explain the why about the universe.
3. Explore and investigate their world in scientific ways.
4. Develop interest for future career in science.
5. Apply knowledge of science to solve problems in real life.

The proposed model which is illustrated in FIGURE 3.1 draws on four main inputs: (1) decision on content and context; (2) information about students' prior ideas in the topic area; (3) perspective on the learning process; and (4) the teacher's practical knowledge of the learning situation.

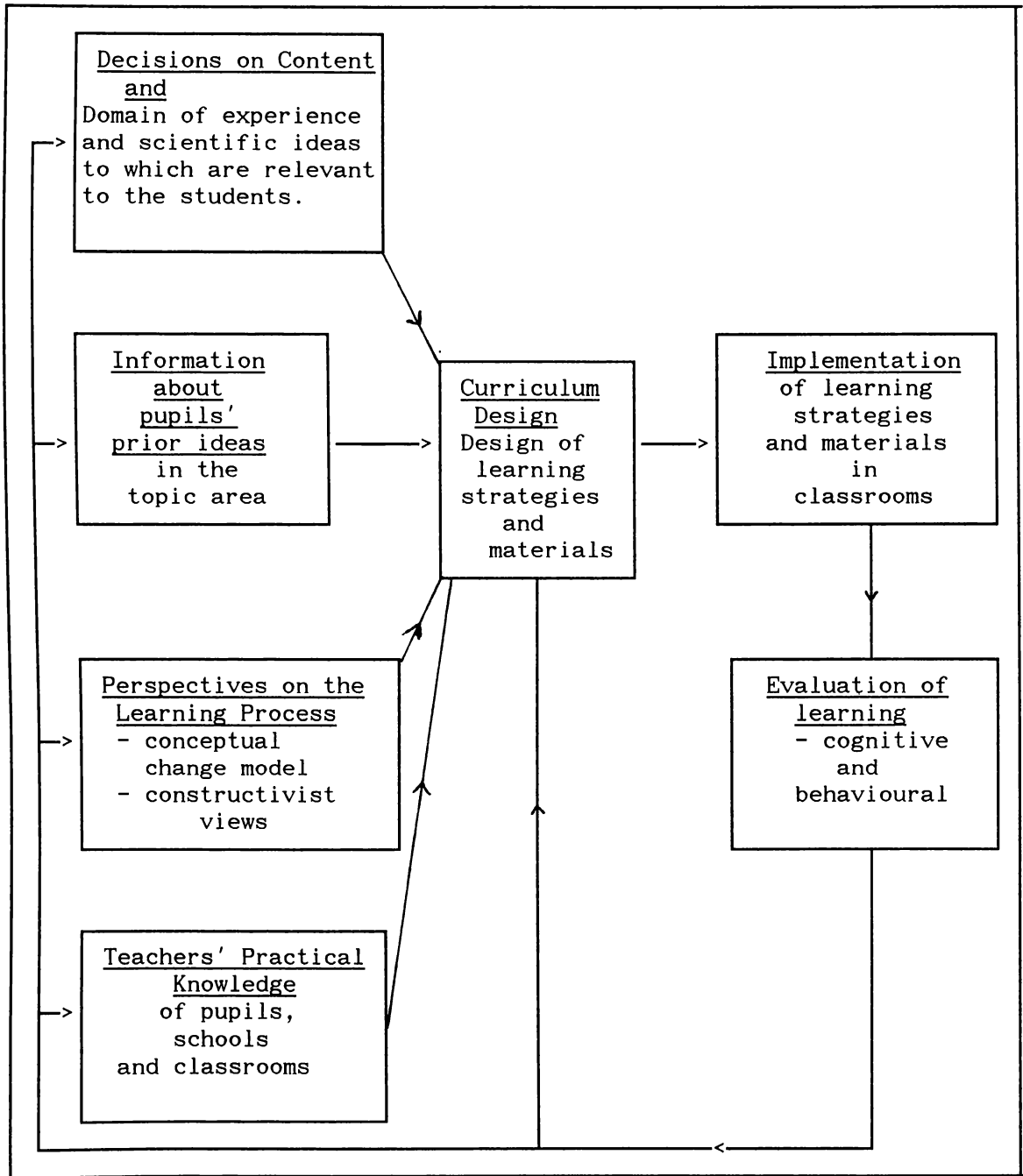


FIGURE 3.1: Proposed General Science Curriculum Model for Junior Secondary Schools in Sierra Leone (After Driver and Oldham, 1985).

3.4.2 Decision on Content and Context

Content

The content of a curriculum is what students learn. This includes understandings, skills and attitudes. Developing understandings and explanations about the natural and technological world is an important goal of science education. Development of the appropriate skills and attitudes enhances students' understanding of that world. The main areas of understandings developed in the proposed junior secondary school science curriculum were drawn from the three core components of science - Physics, Chemistry and Biology. A detailed description of the content area under these three branches is contained in APPENDIX 3.1.

Context

Arguments presented in Chapter Two in particular, suggest that the study of pure or formal science by itself can lead to learning by many students that is irrelevant in their own lives. Identifying contexts in which science should be learnt caters for individual and societal interests.

The context of the proposed curriculum is the real world of the students. This dwells on four main areas:

1. Science and the learner - by relating the content of science to the learners' well being e.g, safety, leisure activities, folk beliefs, and day-to-day living styles.
2. Science and the community - by relating the content of science to community related problems e.g, housing, good sanitation and famine.
3. Science and the environment - by relating the content of science to more generalized problems such as health, agriculture and pollution.
4. Science and indigenous technology - by relating the content of science in understanding principles of indigenous technology in the light of any of the above contexts.

3.4.3 Information about Students' Prior Ideas

Research findings show that students make sense of their world by building on their experiences and prior knowledge. Hence, adopting a view of learning science as a conceptual change requires insight into ideas students bring to the learning situation. Such information may provide a basis for analysing areas of difficulty where students may need particular experiences to develop or change their understanding. It has been argued that the more teachers know about and appreciate students' alternative conceptions, the better they will be able to provide effective learning experiences for their students to modify those conceptions (Sutton, 1980; Gilbert, Osborne and Fensham, 1982).

3.4.4 Guiding Principles for Teaching and Learning

The next two inputs in the curriculum model constitute what is called the guiding principles for teaching and learning. This includes perspectives on the learning process and the teachers' practical knowledge of the learning situation. The instructional guide for the proposed curriculum was based on the constructivist tradition which perceives of learning as coming about through the active construction of meaning by the learner. The teachers' practical knowledge of the learning situation (which includes knowledge of students, schools, classrooms etc) helps to plan, execute and manage the teaching and learning process.

3.5 APPLICATION OF CURRICULUM MODEL IN SIERRA LEONE

The arguments presented in this chapter and the preceeding one tend to indicate some prospects for the teaching and learning of science in non-western countries based on the constructivist Science for All ideology. Propositions like these justify the need for new curriculum model such as the one proposed in this study. It is common knowledge that curriculum innovations undertaken in isolation from teachers' actual involvement seldom have much impact on teaching practices or student learning. From the constructivist tradition, the change process must involve teachers surfacing and challenging their own ideas on the teaching and learning of science. These considerations suggested the present study, the focus of which was working in the

field with science teachers in a non-western country (Sierra Leone) trialling a junior secondary school General Science curriculum model patterned on the constructivist Science for All lines. In broad terms the study entailed first, investigating science teachers perceptions of the existing junior secondary school General Science programme, and later, the effects of the teachers' interaction with a new Science for All curriculum on those perceptions. During the course of the study, the researcher also tapped into the attitudes towards science of students at the junior secondary school level. These broad areas suggested the specific research design and method that are described using the next chapter.

CHAPTER 4: RESEARCH DESIGN AND METHODOLOGY

4.1 RESEARCH QUESTIONS

A review of the research literature, together with the problems raised in the Introduction, gave rise to four research questions that guided the present study. The four research questions were as follows:

1.	What are the attitudes of junior secondary school students in Sierra Leone towards school science?
2.	In relation to the junior secondary school science programme, what are the perceptions of science teachers towards: 2.1 curriculum in General Science; 2.2 the nature of science and ways of acquiring scientific knowledge; 2.3 methods of teaching science; and 2.4 the appropriateness of school science for community living?
3.	What would be the effect of an action research experience with a Science for All curriculum on the professional development of junior secondary school science teachers in Sierra Leone?
4.	What would be the effect of this same curriculum on attitudes towards science of the students of these Sierra Leonean teachers?

4.2 RESEARCH DESIGN

Special difficulties existed in implementing a research design to answer the research questions above. The researcher was able to actually work in the field in Sierra Leone for a short time only and this fact, combined with the high cost of living, travel, communications and resource materials, precluded long-term experimental studies, national surveys, or correlational work with large representative samples of teachers and students. In the circumstances it was decided to adopt an integration of the case study and action research methodologies. This was the most viable approach in the light of the research questions as framed. In addition, this approach fitted with the researcher's belief that any effort to introduce science teachers into accepting alternative ways of viewing and teaching science might best start with examination of their existing views and concerns.

The Case Study was an in-depth investigation of what science teachers perceived about the nature and value of science as taught in the junior secondary school curriculum. It also comprised a large sample survey that investigated junior secondary school students' attitudes to science.

The Action Research, on the other hand, was directly related to the implementation of an innovative model of science curriculum that gave science teachers an opportunity to be their own researchers as to the effectiveness and worthwhileness of this curriculum.

Thus, the research design for both the case study and the action research phases comprised four focuses:

Focus 1. Attitudes to Science Survey (4.2.1 below)

Focus 2. Interviewing and Classroom Observations of Science Teachers (4.2.2 below).

Focus 3. Action Research Development and Trialling of the New Science for All Curriculum Material (4.2.3 below).

Focus 4. Pre and Post Testing of Students' Attitudes to Science (4.2.4 below).

A brief account of each of these activities is given in the following sections.

4.2.1 Focus 1: Attitudes to Science Survey

Like the science teachers, the researcher also believed that students' existing perceptions about the science they study at school are important guides for curriculum innovation studies. However, taking an inventory of what junior secondary school students perceive about the science they learn at school through interviewing, or in situ observations, was not considered sufficient. This decision lay in the researcher's knowledge of children in traditional societies like Sierra Leone. Such students are suspicious of researchers who solicit information from them about 'elders' such as parents or teachers, and they may well be reserved about researchers communicating with their parents or teachers on what they as students say .

On the other hand, questionnaire instruments, especially when the students are informed that analysis will be by computers, tends to minimize their fears. It was primarily on this basis, therefore, that a questionnaire on attitudes to science was selected to probe junior secondary school students' perceptions of the science they study at school.

Additional justification for the use of a questionnaire was the target sample. A questionnaire could sample far more students than individual interviews could within the same given time.

4.2.2 Focus 2: Interviews and Classroom Observations of Science Teachers

Interviews

Interviewing was the major means through which information was obtained from the subjects during both the case study and action research phases (Research Questions 2 and 3).

The approach adopted, particularly during the case study phase, was influenced by techniques described by Glaser and Strauss (1967) as Grounded Theory. This approach has been used extensively at the University of Waikato in New Zealand (e.g., Battersby, 1981), and has been used successfully by researchers in the Learning in Science Project in that same university (Osborne and Freyberg, 1985).

In practice, Grounded Theory suggests that as data emerges, it should generate propositions for further in-depth investigation, the process continuing until such time as propositions become theoretically saturated. In accordance with this dictum, several open-ended interviews were held between the researcher and individual science teachers during the case study phase. The questions and information in these interviews were guided by the broad research questions emerging from the literature review.

Mindful of the Glaser and Strauss (1967) alert that "researchers cannot avoid collecting a large mass of data of dubious theoretical relevance if they fail to take respites for reflection and analysis", the present researcher endeavoured to use elements of their comparative analysis technique. This entailed ongoing analysis of the data as they emerged during the field work, always checking and re-checking patterns for ideas and attitudes against earlier patterns to see if there was really something new or merely confirmation of earlier trend.

The type of interviews that took place between the researcher and the participating teachers during the action research phase were of a slightly different nature. They were more like negotiations between the researcher and the teachers after each trial of a teaching unit, with the discussion in most cases leading to a re-modification of the teaching unit for re-trialling.

Observations

In matters relating to the teaching and learning of science, a gap often exists between teachers' perceptions and their classroom practices. To minimize such anomalies, several classroom observations were employed to augment information obtained through interviewing. These observations were restricted to the research schools only, and

involved the researcher sitting in classes of the case study teachers for selected lessons during both the case study and action research phases of the study.

4.2.3 Focus 3: Action Research: Development and Trialling of the New Curriculum Material

Bolster (1983) noted that ideas and principles about teaching are believed to be true by teachers only when they give rise to action that works in their own classrooms with their own students. Thus, the present researcher worked collaboratively with the case study teachers in the trialling of teaching packages which the researcher was developing with them related to a new curriculum. The intention was to give the participating teachers the opportunity to evaluate a curriculum model that they had helped to develop (see 4.5.4 below).

4.2.4 Focus 4: Pre and Post Testing of Students' Attitudes to Science

To answer Research Question 4, it was necessary to develop a measure of changes in students' attitudes before and after their experience with the new curriculum. In addition to the teachers' intuitive judgements, the researcher used the questionnaire on attitudes to science as a pre and post surveys.

4.3 THE MAIN RESEARCH METHODS IN THE STUDY

This section provides a brief examination of the strengths and weaknesses of the two main research methodologies employed in the present study: case study and action research. A review of the theoretical bases of social science research methodologies is provided in APPENDIX 4.1.

4.3.1 Case Study Research Methodology

Nisbet and Watt (1978) see case study as an umbrella term for a family of research methods having in common the decision to focus an enquiry around a unit e.g., a person, a classroom, a single school, a group of schools, a group of people such as teachers. The collection of data

usually involves the frequent and sometimes simultaneous use of a number of interviews, observations, questionnaires and document-gathering techniques. The aim is to probe deeply, and to analyse intensively, the multifarious phenomena that constitute the life cycle of the unit with a view to establishing generalizations about the wider population to which that unit belongs.

As indicated earlier, in part the selection of the case study approach for the present study was justified on the grounds that teachers in developing countries are hardly ever actively involved in curriculum innovation projects. Or again, when input from them is required, this has mostly been obtained through paper and pencil questionnaires administered on a large scale. But questionnaires seem to be inadequate as tools to explore the day-to-day problems faced by teachers. The case study approach was therefore employed to probe a small sample of science teachers' existing perceptions about general science. The goal was to put the case study teachers' existing views at disequilibrium in readiness to be confronted with alternative views contained in a proposed new curriculum model for them to try out.

The case study approach, particularly when it involves techniques such as participant observation, has inherent advantages which Bailey (1978) has identified as follows:

1. Observation studies are superior to experiments and surveys when data are being collected on non-verbal behaviour.
2. In the observation study, the investigator is able to discern ongoing behaviour as it occurs and is able to make appropriate notes about its salient features.
3. Because case study observations take place over an extended period of time, researchers can develop a more intimate and informal relationship with those they are observing, generally in more natural environments than those in which experiments and surveys are conducted.
4. Case study observations are less reactive than other types of data-gathering methods. For example, in laboratory-based experiments and in surveys that depend upon verbal responses

to structured questions, bias can be introduced in the very data that the researcher is attempting to study.

(Source: Cohen and Manon, 1986, pp.124-125)

Like all other research methods, the case study approach also has some disadvantages. The accounts that typically emerge, especially those from participant observations, are often described as "subjective, biased, impressionistic, idiosyncratic and lacking in precise quantifiable measures" (Cohen and Manion, 1986, p.125). Furthermore, the data collection techniques of case studies have what Nisbet and Watt (1978, p.20) described as the "luxury and dilemma of being the chief instrument". The implication is that the success and failure of case studies depends on a researcher's ability to develop good personal relationships with the subjects studied in order to have access to the data sought and thus give validity to the findings. This invariably commits researchers to personal face-to-face interaction with their subjects.

While this approach enables researchers to gather a rich array of in-depth data, the pitfalls raise questions about the reliability and validity of such techniques.

A major weakness however - not unique to case study techniques alone - is the practice of the educational researcher standing aloof from the problem(s) under investigation. In many case studies, research activities are planned to terminate at the diagnostic stage. There are no efforts on the part of researchers to apply a treatment to the problem under investigation, and critically evaluate the effects of that treatment *in situ*.

To overcome such limitations, action research was selected as the second research methodology in the present study. As stated before, this action research was to involve a teacher sample in the formulation, trial and evaluation of the proposed Science for All curriculum model. The main features of the action research methodology are summarized in the following section.

4.3.2 Action Research Methodology

Educational action research is a term that describes a family of activities in curriculum development and school improvement programmes, system planning policy and development. A comprehensive definition of the term is difficult because its usage varies with time, place and setting (Cohen and Manion, 1986).

According to Hasley (1972), action research is a small scale intervention in the functioning of the real world and a close examination of the effects of such interventions. Carr and Kemmis (1986, p.164) describe action research as consisting of "analysis, fact-finding and conceptualisation about problems, planning of action programmes, executing them and then more fact-finding or evaluation and then a repetition of this whole cycle of activities; indeed a spiral of such cycles". Such a cycle is best illustrated in the diagram below:

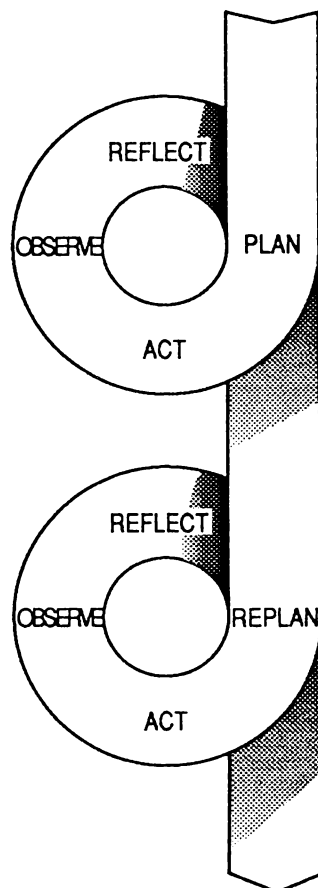


Figure 4.1: The Cyclic Process of Action Research (after Coveill, 1986).

Cohen and Manion have summarised the distinctive features of action research as follows:

Situational :	It is concerned with diagnosing a problem in a specific context and attempting to solve it in that context.
Sometimes collaborative :	Teams of researchers and practitioners work together on a project.
Participatory :	Team members themselves take part directly or indirectly in implementing the research.
Self-evaluative:	Modifications are continuously evaluated within the ongoing situation, the ultimate objective being to improve practice in some way or the other.

(Cohen and Manion, 1986, p.208)

The use of action research in the social sciences occurs in two stages: (1) a diagnostic stage in which the problems are analysed and the hypotheses developed, and (2) the therapeutic stage in which the hypotheses are tested by a consciously directed change experiment.

Action research as a method has wide scope in its application. Its usage may range from a teacher trying out a novel way of teaching with his/her class, to a sophisticated study of organizational change in industry using a large research team. Whatever the situation, Cohen and Manion (1986) claim that the method's evaluative frame of reference remains the same, namely, to add to the practitioner's functional knowledge of the phenomena with which s/he is dealing.

The application of action research in school classroom investigations falls broadly into five categories:

1. It is a means of remedying problems diagnosed in specific situations, or of improving in some way a given set of circumstances.

2. It is a means of in-service training, thereby equipping teachers with new skills and methods, sharpening their analytical power and heightening their awareness.
3. It is a means of injecting additional or innovatory approaches to teaching and learning into an ongoing system which normally inhibits innovation and change.
4. It is the means of improving the normally poor communication between the practising teacher and the academic researcher.
5. It is the means of providing a preferable alternative to the subjective, impressionistic approach to problem solving in the classroom.

A principal justification for the use of action research in the context of the school is the cooperative spirit it engenders among teachers. Because problems of teaching are often shared with other teachers in the same school, action research has tended to become cooperative involving many or all of the teachers in a school. It tends, therefore, to enhance group interaction among teachers.

Many researchers believe that action research is a methodology that creates data, but does not (as yet) interpret data (Winter, 1982). Notwithstanding this idea, action research has proven to be most effective for curricular and educational change in a variety of educational settings (Smith and Lovat, 1990), hence the researcher's justification for choosing this method for the present study.

Discussion in the preceding sections has outlined reasons for the selection of the research methodologies that were employed to obtain data for this study. The following sections describe the research samples used and the data collection procedures.

4.4 RESEARCH SAMPLES

In keeping with the research questions and design, the present study required several kinds of research sample:

1. The research schools for both the case study and action research work.
2. Schools for a large sample survey of science attitudes.
3. Sample of students and teachers for the case study and action research.

4. Sample of teacher educators in science.

Apart from the large sample survey of attitudes to science which was conducted in three of the four provincial headquarters in Sierra Leone, the main part of the study (i.e. the case study and the action research work) was undertaken in and around Bo. As the second largest town in Sierra Leone, Bo is semi-urban with a population of approximately 120, 000 people. Situated almost at the centre of the country, from colonial times the town has been the provincial headquarters of the Southern Province and, along with Freetown the capital of Sierra Leone, continues to be a major administrative centre. Not surprisingly, the majority of the town's inhabitants are either government workers or traders.

Even though Bo is located in the heartland of the Mende (the largest ethnic group in Sierra Leone), the ethnic composition of the population is heterogenous representing almost all the tribes in the country. Both the teaching and student population represent all the major ethnic compositions in the country. This factor was considered important for a science curriculum innovation that had cultural undertones (as was to be the case in the present study).

4.4.1 The Research Schools

To gain access to the schools, a letter of approval introducing the researcher and his mission in Sierra Leone was obtained from the Permanent Secretary of the Ministry of Education. The letter was addressed to principals of secondary schools and requested that permission be granted to the researcher to work in schools he so desired. A photocopy of this letter is included in APPENDIX 4.2. Permission from principals in all schools visited was automatic, and principals introduced the researcher to Heads of Science Departments with whom the researcher maintained cordial working relationships throughout the study.

In addressing Research Questions 2-4, the researcher decided to work with three secondary schools in and around Bo. From 17-21 April 1989, the researcher visited eleven secondary schools in Bo from which two schools were selected. The criteria for selection were:

1. That teachers who participated in the research which commenced in the third term of the 1988/89 school year did not change schools during the 1989/90 school year.
2. That the participating teachers were professionally trained and qualified.
3. That the participating teachers represent the three branches of general science teaching (Chemistry, Biology and Physics) in the third term of the 1988/89 school year.

While three schools had science teachers who fulfilled all three conditions, one of them, the Ahmadiyya secondary school, is a Moslem institution with week days starting on Sunday. Consequently, only the Bo Government and St. Andrews secondary schools were selected.

The Bo Government Secondary School, founded by the colonial government in 1905, is a non-religious boys' boarding school. The school is patterned on the English grammar school system and was established originally to train the sons of chiefs - the future rulers. The segregative practice of training only the sons of chiefs has gradually been phased out. Because the school is one of the cheapest in terms of school fees, it attracts intelligent primary school graduates from all parts of the country.

The student population is 900 spread over Forms 1 to 6. The school was one of three in the 56 secondary schools of the southern province that had Sixth Form science components. The school has four well established laboratories: two biology, and one each for chemistry and physics.

There were four Form 1 and three Form 2 streams studying general science in this school. The average number of students per stream was 40 and 45 for Forms 1 and 2 respectively. Students were streamed according to their academic abilities. The 01 streams were for the above average students, 02 the average, and 03 and 04 were for the below average groups. There were five teachers of General Science in Forms 1 and 2.

St. Andrews Secondary School was founded in 1954 by the United Methodist Mission and is a coeducational institution. It has a student population of about 1100 spread across Forms 1 to 6. Unlike

the Bo government secondary school, St. Andrews draws most of its students from primary schools in and around Bo town. The school has two laboratories, one for biology and one that combines chemistry and physics.

There were four streams each for Forms 1 and 2, with an average of about 40 students per stream. Like Bo school, students were streamed according to their academic abilities. The White streams were for the above average students, Green for the average, and the Blue and Yellow streams for the below average students. General Science in Forms 1 and 2 was taught by six teachers.

The Gerihun Agricultural and Vocational Secondary School, the third research school, was purposefully selected by the researcher to represent the minority of secondary schools located in rural areas. Rural here refers to settlements in which:

1. the main source of water for drinking and other purposes is obtained from running streams or shallow hand-dug wells;
2. people use three firestone stoves for cooking; and
3. the majority of the members live in family-shared houses built of sticks and mud with zinc roofing.

In addition, Gerihun is located about 18 kilometers East of Bo on a major motor road, and was easily accessible to the researcher who was resident in Bo. Students from this school were selected to help the researcher determine how traditional children in rural schools reacted to the idea of the new science curriculum.

The school was founded by the Catholic Mission in 1972 in response to the growing number of children from the area who had to move to distant big towns to pursue secondary school education. The school curriculum initially emphasized vocational training. Since the majority of the students hailed from the surrounding villages where peasant farming is the main occupation, agriculture was to be a core area of study. The school had a palm oil farm, an orchard and a fish pond.

The student population was made up of 250 boys and girls. The yearly drop-out rate, according to the Head of Science Department, was very

high (he figured a rate between 40 to 50 per cent, with higher figures for girls). There was one laboratory used for chemistry and biology practicals. Physics was not studied up to Form 5 level because of the lack of staff and laboratory facilities. There was one stream each for Forms 1 and 2, with an average of 35 students per stream. General Science in the two junior Forms was taught by one teacher.

4.4.2 Schools and Students for the Large Sample Survey of Science Attitudes

Ideally, Research Question 1 required a very large representative sample from junior secondary schools across the whole nation. As discussed in Section 4.2 above however, circumstances precluded this. Consequently, the attitudinal questionnaire was administered in nine secondary schools only (n=806 students). Selection of the nine schools for the science attitudes survey was based on the researcher's knowledge of schools with comparable staffing and physical facilities. Three schools each were selected from both eastern and western provinces, one boys' school, one girls' school and one co-educational school. For the eastern province, three schools were selected from Kenema, the headquarters of eastern province. Similarly, three schools from the western province were selected from Freetown.

In the southern province where the research schools consisted of one boys' school and two co-educational schools, one girls' school was selected from Bo to replace one of the co-educational research schools. The school at Gerihun was left out because of the students' inability to understand the questionnaire items. From each of the nine schools, students from the average ability stream were selected to constitute the subjects for the large sample attitude survey.

Particulars of the nine secondary schools that constituted the sample for the science attitudes survey are shown in APPENDIX 4.3.

4.4.3 Sample of Students and Teachers for Case Study and Action Research

* Sample of Students

Student streaming at both the Bo government and the St. Andrews secondary schools was based on students' academic ability as determined by either their primary school leaving results or their last promotional examination results. To avoid the tendency of working with extreme cases, General Science classes of the average ability streams were selected to constitute the sample of student classes for the classroom observation during the case study phase. These classes represented the Forms 102 and the 202 streams at the Bo government secondary school, the Forms 1 and 2 Green streams at the St. Andrews secondary school, and the single Forms 1 and 2 streams each at the Gerihun secondary school. The action research involved all streams of Forms 1 and 2 in the three research schools, even though the actual trial and retrieval lessons of the new curriculum materials were only conducted in the 02 and 03 streams at Bo school, and the Green and Blue streams at St. Andrews school.

The composition of sample classes of students for both the large survey and the case study and action research work is summarised in FIGURE 4.2.

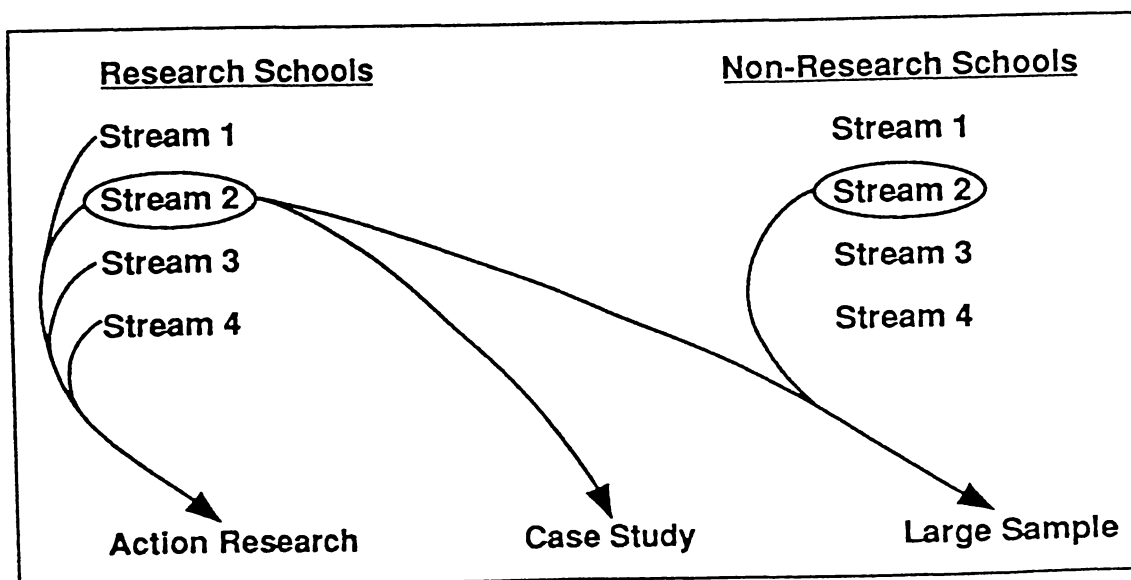


Figure 4.2: Classification of Forms 1 and 2 Streams of Students Included in the Study

* Sample of Teachers

General Science teachers of the average ability streams of students from the Bo government and St. Andrews secondary schools, plus the single General Science teacher from the third research school at Gerihun, constituted the sample of the case study and the action research teachers. The group consisted of five out of a total of twelve General Science teachers in the three research schools. The teaching experience of these teachers ranged from four to eight years, with the majority of them having been teaching in their respective schools for the past two years.

Apart from teaching General Science in Forms 1 and 2, four of the sample teachers were also teaching either Biology or Agriculture at the senior secondary level in their schools. A resume of the case study teachers alongside those of other General Science teachers in the three research schools is shown in FIGURE 4.3.

In addition to the five case study teachers, Heads of Science Departments from the three research schools were included in the study. Their inclusion arose out of in situ observation. In the absence of a national General Science curriculum, Heads of Science Departments drew up topics that constituted the General Science syllabi in their various schools.

Therefore, their inclusion in a curriculum innovation exercise such as the one undertaken in this study was deemed necessary. Their addition to the other five teachers brought the total number of participating teachers to eight males.

The exclusion of female representation was a consequence of the limited number of female science teachers in Sierra Leone. There is one female only in every ten science teachers at the secondary school level. Female science teachers carry the responsibility of caring for their families in addition to their school tasks. Marian, the only female out of the twelve General Science teachers in the three research schools, declined to participate in the study because of domestic commitments.

Name of School	Name of Teacher	Form Taught	Qualification	Major Subject Studied	Teaching Experience
Bo Govt. Sec.	John Moriba *	2, 4, 5, 6	B.Sc. Ed.	Biology	6
	Marian Murray	1, 2, 4	B.Sc. Ed.	Biology	4
	Albert Yanguba *	1, 4, 5	B.Sc. Ed.	Agriculture	8
	Alfred Kassay	2, 3, 4	B.Sc. Ed.	Agriculture	6
	Joseph Toko	1, 2	A Level	-	1
St. Andrews	Joseph Gbenjeh	1	A Level	-	2
	Martin Juana	1	A Level	-	1
	Unisa Turay *	1, 4	H.T.C.	Agriculture	4
	Bashiru Koroma	2, 5	B.Sc.	Agriculture	2
	David Ansumana	2, 3	H.T.C.	Biology	4
	Joseph Sandi *	2, 4	B.Sc.Ed	Agriculture	4
Gerihun Agricultural and Vocational	Paul Tucker *	1, 2	H.T.C.	Biology	6

* Case Study Teachers

FIGURE 4.3 : RESUME OF GENERAL SCIENCE TEACHERS IN RESEARCH SCHOOLS DURING THE 1988/89 SCHOOL YEAR

For the purpose of answering Research Question 2.1, particulars of General Science teachers from the nine schools selected for the survey on science attitudes were obtained through the permission of the principals of those schools. Together with the research school at Gerihun, a resume on General Science teachers from ten secondary schools in Sierra Leone is shown in APPENDIX 4.4.

4.4.4 Sample of Teacher Educators in Science

The fourth category of samples for data collection was the secondary school teacher educators in science. As a way of cross-checking information furnished by science teachers relating to their pre-service training, a selected number of their trainers was contacted who consented to be interviewed by the researcher. The number included one professor of Science and Curriculum Development, three members of the Faculty of Education at Njala University College, and one lecturer from the Milton Margai Teachers College in Freetown. The three faculty members included a lecturer in Educational Philosophy and one time Head of Department of Education at Njala University college, a lecturer in Agricultural Education, and a lecturer from Agricultural Extension.

4.5 DATA COLLECTION

The data collection for this study commenced in April 1989 and ran through to January 1990 (see FIGURE 4.4) and, as indicated above, involved five research procedures:

1. An attitudes to science questionnaire.
2. Interviews.
3. Classroom observations of science lessons.
4. Teachers' self- evaluation questionnaire.
5. Action research.

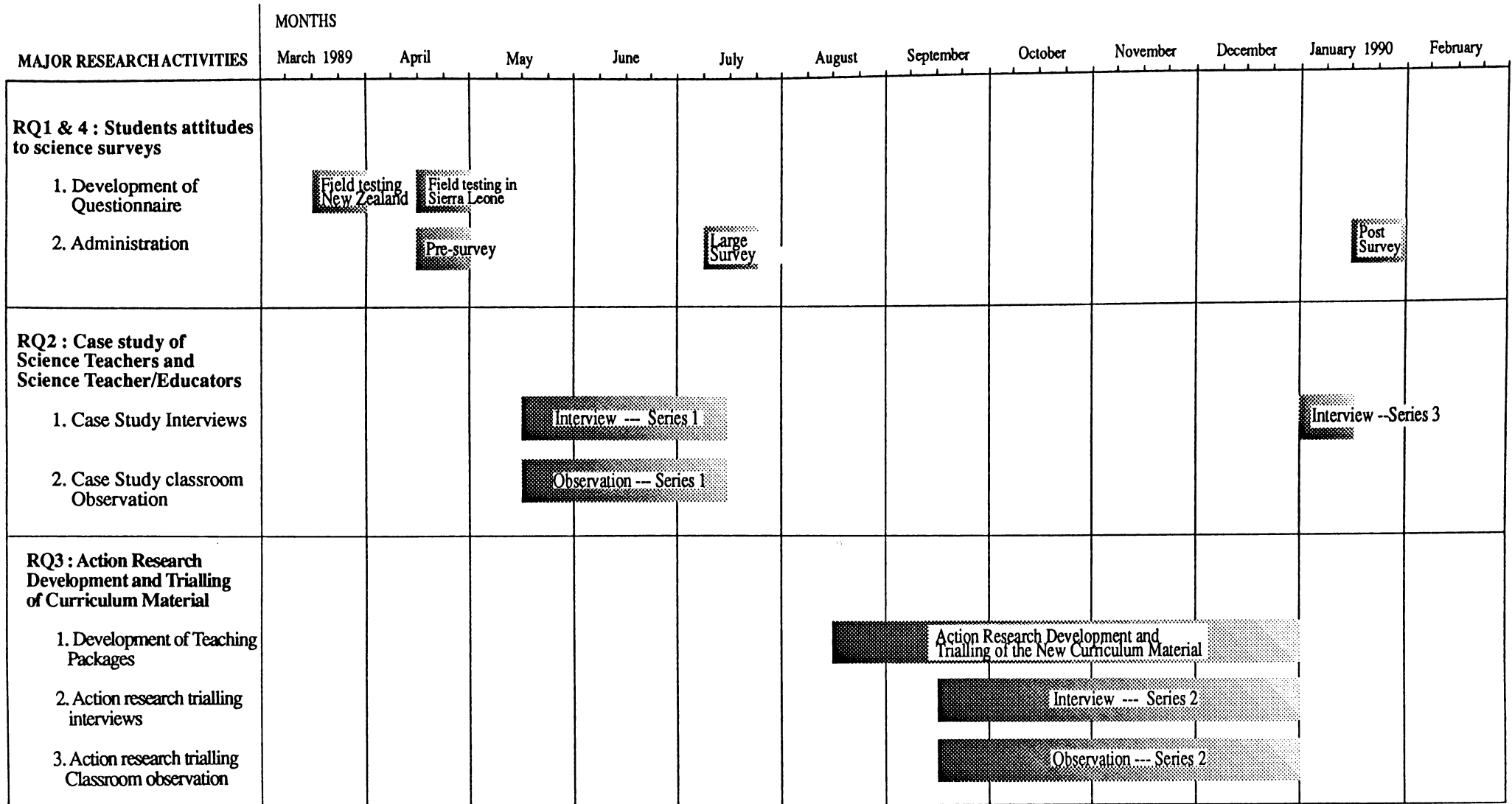


Figure 4.4: Research Timetable

4.5.1 Development and Administration of the Attitudes to Science Questionnaire

Development

The questionnaire used in the present study was a modified version of the Test of Science-Related Attitudes (TOSRA) developed by Fraser (1981) in Australia. This instrument had attempted to take account of eight characteristics of science that Kimball (1967-68) had identified as a sound basis for making an inventory of student attitudes about science. These characteristics are as follows:

1. The fundamental driving force in science is curiosity concerning the physical universe. It has no connections with outcomes, applications, or uses aside from the generation of new knowledge.
2. In the search for knowledge, science is process-oriented, it is dynamic ongoing activity rather than a static accumulation of information.
3. In dealing with knowledge as it is developed and manipulated, science aims at ever - increasing comprehensiveness and simplification, emphasizing mathematical language as the most precise and simplest means of stating relationship.
4. There is no one "scientific method" as often described in school science textbooks. Rather, there are as many methods of science as there are practitioners.
5. The methods of science are characterized by a few attributes which are more in the realm of values than techniques. Among these traits of science are dependence upon sense experience, insistence on operational definitions, recognition of the arbitrariness of definitions and schemes of classification or organization, and the evaluation of scientific work in terms of reproducibility and of usefulness in furthering scientific inquiry.
6. A basic characteristic of science is a faith in the susceptibility of the physical universe to human ordering and understanding.
7. Science has a unique attribute of openness, both openness of mind, allowing for willingness to change opinion in the face of evidence, and openness of the realm of investigation, unlimited by such factors as religion, politics, or geography.
8. Tentativeness and uncertainty mark all of science. Nothing is ever completely proven in science, and recognition of this fact is a guiding consideration of the discipline.

(Kimball, 1967-68, pp.111-112).

The TOSRA was designed to be used with junior secondary school students (10-14 years) and has seven science-related attitude scales:

1. Social implications of science
2. Normality of scientists
3. Attitudes to inquiry
4. Adoption of scientific attitudes
5. Enjoyment of science lessons
6. Leisure interest in science
7. Career interest in science

There are ten Likert-type items for each scale, making a total of 70 items.

For the purposes of the present study, the TOSRA was modified in two ways: (1) scales were included on student appraisal of the Application of Knowledge of School Science in everyday life and Understanding the Nature of Science, and (2) items in all scales were checked for their readability level and, if considered above the reading level that Sierra Leonean students at junior secondary school level could handle, were re-written in more appropriate language.

The two new scales (Application of Knowledge of School Science and Understanding the Nature of Science) were substituted for Fraser's Social Implications and Normality of Scientists scales. The present researcher evaluated that item statements in these two latter scales would make little or no sense to Sierra Leonean students. The new scale on Application of Knowledge of School Science was an original formulation by the present researcher, while the scale on Understanding the Nature of Science was derived from Ruba's (1978) instrument.

The modified questionnaire, then, comprised seven Likert-type scales, each having 10 items, making a total of 70 items. As indicated above, to avoid the danger of results being distorted due to reading comprehension problems, the items were simplified to be at the expected reading level of Sierra Leonean students for whom English is a second language. Initially, items were reconstructed by the researcher and another scientist whose first language is English, with care being taken not to lose the conceptual meaning in the original

item statements. Subsequently, a panel of six graduate students in science education cross-checked all items for such conceptual loss and the few problematic items received corrective writing treatment.

The modified TOSRA was field tested twice, first in New Zealand and later in Sierra Leone. In New Zealand, the questionnaire was given to 33 Form 4 students from a Hamilton high school. On average, students spent 40 minutes answering the 70 items and the informal discussion that followed indicated that the students clearly understood both the directions and content for the instrument. An SPSS computer programme showed that the internal coefficient reliability alpha for the modified instrument, ranged from 0.3 - 0.95 with a mean of .71 (this is compared to an .81 mean value for that age of students in the original TOSRA instrument). The discriminant validity (the extent to which a given scale measures a unique attitude not measured by other scales in the instrument) gave a mean value of 0.25 as compared to 0.33 in the original TOSRA instrument. Despite somewhat lower alpha coefficient and discriminant validity values, the range for the modified instrument was reasonable and the instrument was thus considered acceptable.

In Sierra Leone the questionnaire was field tested with one average ability stream each of Forms 1 and 2 students in two co-educational secondary schools. These students were asked to call the researcher's attention to any difficult words or phrases that they encountered in the questionnaire items. The average time taken to answer the questionnaire was 60 minutes, with the slowest students taking 70 minutes. On the whole the students found few problems with the items, even with those written in negative form. Re-writing was minimal. The final questionnaire that was used for data-gathering may be found in APPENDIX 4.5. The answer sheet for the questionnaire is shown in APPENDIX 4.6.

* Reliability of the Attitudes to Science Questionnaire

In spite of the extensive re-development of the TOSRA, the reliability of the adopted test ranged from moderate on some scales, to low on others. As shown in TABLE 4.1, the alpha coefficient values for the New Zealand sample were close to or above 0.7. The values for the Sierra Leonean students were far less. Only four of the seven scales

TABLE 4.1 Cross-validation data from New Zealand and Sierra Leone

SCALE	N E W Z E A L A N D (N = 33)		S I E R R A L E O N E (N = 806)			
	Alpha Reliability	Mean Correlation with Other Scales	Alpha Reliability		Whole Sample	Mean Correlation with other scales
			Form One	Form Two		
Application of Scientific Knowledge	0.65	0.61	0.27	0.27	0.29	0.36
Understanding Nature of Science	0.30	[- 0.11]	0.07	0.05	0.06	[-0.11]
Attitudes to Scientific Inquiry	0.73	0.25	0.50	0.51	0.52	0.18
Adoption of Scientific Attitudes	0.56	0.46	0.30	0.37	0.35	0.31
Enjoyment of Science Lessons	0.95	0.62	0.42	0.58	0.52	0.41
Leisure Interest in Science	0.88	0.59	0.54	0.62	0.59	0.41
Career Interest in Science	0.89	0.58	0.55	0.62	0.59	0.30

Note: Values in brackets [] not included in computing mean correlation with other scales.

has alpha coefficient values above 0.5 for this group. It should be no surprise that students in a totally different cultural context have different interpretations of the Test of Science Related Attitudes questions.

The effect of a reduction in coefficient alphas is to reduce the chances of detecting differences between groups on their scale scores. In terms of traditional test theory, low reliability means that the ratio of scale variance to error variance has decreased and consequently the power of statistical tests involving the scales will decrease. For this reason the scale on understanding of the nature of science which had very low alpha coefficient even with the New Zealand students carried no statistical significance in the interpretation of students' attitudes to science results. The other scales although having moderate or low alpha coefficients were consistent in detecting differences between the various factors. Furthermore, a factor analysis test provided confirmation that the items developed in Australia have similar meaning for the Sierra Leonean students.

A principle components analysis of the tests answered by the 806 students was carried out. The factors were rotated to produce an oblique factor solution using an oblimin rotation method. Factorisation occurred until 7 factors had been extracted.

The factor pattern matrix revealed that of the seven factors extracted four seemed to correspond to the scales from the science-related attitudes instrument. A fifth factor seemed to be a composite of two scales from the science-related attitudes instrument. TABLE 4.2 gives the correspondences and number of items corresponding. Details of statistical information on the factor analysis is contained in APPENDIX 4.7.

Administration

As stated earlier, the questionnaire on attitudes to science was used for a large sample survey and as a pre and post-test instrument. In both cases administrative procedures were the same, the researcher being assisted by a team of four assistants who were final year physics students at Njala University College.

TABLE 4.2 Factor Correspondence with Science-related
Attitudes Scale

Factor from F.A.	Correspondence with Science-related attitudes scales	Range of Correlations of Items with Factors
I	5 out of 9 items from scale 1	0.44 - 0.195
II	6 out of 14 items from scale 7	0.71 - 0.27
III	No apparent correspondence	
IV	9 out of 9 items from scale 3	0.62 - 0.30
V	4 out of 8 items from scale 2	0.62 - 0.15
VI	No apparent correspondence	
VII	4 items from scale 6 and 6 items from scale 5 out of 16 items	0.59 - 0.23

In all administrations the sample students were taught first of all how to answer a Likert-type questionnaire by having them respond to generalized statements about matters other than science ones (e.g., *Education for women is unimportant. School Prefects should be given more power to punish troublesome students. Religious Studies should be compulsory in all schools. I find Mathematics boring*). It was important in this preliminary work that students realized that their opinion was being sought about each questionnaire item, and that it was not a matter of having a right or wrong answer.

Each questionnaire administration followed the same pattern: the researcher handled the introductory practice work with Likert-type items and directions for the questionnaire, then moved to another group, leaving an assistant to supervise and respond to any questions about difficult words or phrases. The overlap pattern created here in each school prevented any class communicating with another about the content of, or their reactions to, the questionnaire. In all schools a total of 80 minutes per stream was allocated for administration of the questionnaire.

In using the questionnaire for pre and posttesting purposes, it was decided to work in two of the three research schools only, St Andrews and Bo government secondary schools. This was because preliminary work on the questionnaire at Gerihum school revealed serious deficiency in English with both the Form 1 and Form 2 students. In the pretest phase the researcher used all Form 1 and 2 students at both Bo government and St. Andrews secondary schools (see FIGURE 4.2). This was for 2 reasons: (1) the students' responses would be included alongside those of students in the large sample survey, and (2) if average streams only had been used, the chances were that some of the pretest sample would have been lost due to changes in class composition at the end of the academic year.

The pretest use of the questionnaire in the two schools took place 28 April, 1989 with 603 Form 1 and Form 2 students. Posttesting in these same two schools was in January, 1990 and involved 322 students, these being the Form 1 students of the 1988/89 school year who had by this time progressed to Form 2. The large sample survey was administered at Kenema and in Freetown on the 18 and 21 July 1989 respectively.

Including the average ability stream of students from the Bo government and the St. Andrews secondary schools, data was obtained on 806 students (412 Form 1 and 394 Form 2) for the large sample survey.

4.5.2 Interviewing/Observation with Participating Teachers and Teacher Educators in Science

The present study involved three interview/observation series as follows:

- Series 1: School Case Study interviews with eight teachers (INTERVIEWING & OBSERVATIONS).
- Series 2: Trialling of new curriculum-continuing interviews with the same eight teachers (INTERVIEWING & OBSERVATIONS).
- Series 3: Teacher Educators in Science (INTERVIEWING ONLY).

* Series 1: Interviews/Observations

This series took place early in the study (see FIGURE 4.4). The purpose was to identify what the eight teachers involved thought were issues in the teaching of science at the junior secondary school level. Even though the researcher went into the field with a set of research questions, these first interviews were kept informal, fairly general in nature, and took place therefore in the teachers' own homes.

Sultana (1987) recommends that less structured interviews give greater opportunity for probing questions and thus for uncovering new clues to, and dimensions of, a problem. Thus the present researcher took care not to be too specific too early in his interviewing. Typically, his questions were along the following lines:

- * *What is the importance of General Science to the students?*
- * *Do you enjoy teaching General Science?*
- * *What do you think are the feelings students have about the subject?*
- * *Why is it that very few students study science at the senior secondary school level?*
- * *What are the sort of topics you teach in General Science?*

The number of times a particular teacher was interviewed depended upon availability and upon the need to follow up from a previous interview. Circumstances permitted almost all interviews to be audiotaped and transcribed. On average, each teacher was interviewed at least twice (see TABLE 4.3). The interviews were examined for categories of thinking in them about issues in the teaching of science, and for setting up questions for further interviewing. Over the interview series the researcher followed the guidelines of the Grounded Theory approach (Glaser and Strauss, 1967) to refine categories or frameworks. This work was helped by data from an interview with the whole group of eight teachers. The purposes here were: (1) to afford the teachers an opportunity to react to the researcher's summary of the interview series, and (2) to effect a consensus on the categories of belief about science teaching, as well as to record any minority or individual viewpoints.

The interviews above were paralleled by observations of five of the eight teachers from the three research schools in their science classrooms (three of the eight were heads of departments and taught upper classes only). TABLE 4.4 shows the observational schedule which involved two teaching sessions every week for each teacher over a period of eight weeks. Both Form 1 and Form 2 average stream classes were observed. All observations were of double teaching periods (80 minutes).

It was made clear to the five teachers that the researcher's observations were not intended to evaluate them as practitioners, but simply to provide the researcher with first hand information on what goes on in General Science classes. For all observations, the researcher arrived at least 30 minutes early to facilitate a short dialogue with the teacher about the topic of the day. It was the researcher's policy not to influence the way the teachers took their science sessions. Occasionally, however, teachers did ask for advice and, because this was minimal or a teacher seemed somewhat insecure, the researcher offered some assistance. In general, nevertheless, the teachers worked very much on an independent basis. At the end of each session informal discussion between the researcher and teacher helped to build trust in the former as a neutral observer. Whenever possible, audiotapes supplemented field notes for data-gathering purposes.

TABLE 4.3 : A NUMBER OF CLASSROOM OBSERVATIONS AND INTERVIEWS WITH PARTICIPATING TEACHERS

Name of School	Name of Teacher	Form Taught	Branch of General Science Taught	No. of Classroom Observations	No. of Planned Interviews
Bo Govt. Sec.	T. Ngawuja *	6	-	-	3
	J. Moriba	2	Physics	7	4
	A. Yanguba	1	Chemistry and Biology	1	
				6	2
St Andrews	S. Navo *	5	-	-	2
	J. Sandi	2	Physics	5	2
	U. Turay	1	Chemistry	6	3
Gerihun Agricultural & Vocational	J.S. Sandi*	4 and 5	-	-	1
	P. Tucker	2	Biology	5	3
		and	and		
		1	Physics	2	

* Heads of Science departments.

TABLE 4.4 Researchers' Weekly Monitoring Schedule During Eight Week Period of the Third Term of the 1988/89 School Year

	8.:8.40	8:40-9:20	9:20-10:0	10-10:40	11-11:40	11:40-12:20	12:20-1.00	1-1:40
Monday	Gerihun Mr Tucker (Form 2)						Bo School Mr Moriba (Form 2)	
Tuesday				Bo School Mr Yanguba (Form 1)				
Wednesday	Gerihun Mr Tucker (Form 1)						St An rews Mr Sandi (Form 2)	
Thursday				Bo School Mr Yanguba (Form 1)				
Friday					St Andrews Mr Turay (Form 1)		St Andrews Mr Sandi (Form 2)	

* Series 2: Interviews/Observations

This series continued with the eight case study teachers doing their action research experience with a new science curriculum over the period September-December, 1989 of the 1989/90 school year (see FIGURE 4.4). The interviews were held immediately after trial lessons. While both the researcher and teacher were involved in evaluating each teaching session, the teacher was encouraged to initiate such activity. It was hoped that the latter strategy would avoid the possibilities of the teachers feeling that the researcher was an 'examiner', or that they should always agree with him as an authority figure.

Joint evaluations led to modifications in subsequent teaching work. In addition to after-lesson interviews, regular meetings were held on eight week-ends during which the teachers and the researcher co-planned work for the following week.

A group interview of all eight teachers was held in January, 1990 to complete a final evaluation of the new curriculum. Proceedings here were audiotaped and later transcribed. As explained below in Section 4.5.4 the final group evaluation also included four General Science teachers who were not part of the research sample. These teachers had been working independently with the new curriculum material and were not part of the action research programme proper.

Observation work was an integral part of the action research part of the study, and was completed by the researcher using the same schedule as shown in TABLE 4.4.

* Series 3: Interviewing Only

Interviews with teacher educators in science took place in January 1990. One individual interview was held with the professor of Science and Curriculum Development, and one group interview took place with the three members of the Faculty of Education at the University of Sierra Leone. The interview with the professor was in his residence, while that with the faculty members took place in the educational philosophy lecturer's office. Both interviews were semi-structured

and related to the categories about science teaching issues identified by the teachers' in the Series 1 interviews. All interviews were audio taped and transcribed.

It was not possible for the researcher to interview any of the teacher educators in science from the Milton Margai Teachers College during the course of the fieldwork. Hence, the only information from teacher educators from this college was obtained through correspondence between the researcher and one lecturer from the Department of Biology.

4.5.3 Teachers' Self Evaluation Questionnaire

Development

It was learnt during the case study phase that science teachers were not accustomed to keeping daily records of their ideas as required by the researcher. Hence, a self evaluative questionnaire was developed by the researcher during the trialling phase of the teaching packages. The aim was to enable the trial case study teachers to keep a record of every lesson taught. Furthermore, the questionnaires were intended to enable the researcher to evaluate lessons he could not observe. A copy of that questionnaire is shown as APPENDIX 4.8.

Administration

The teachers' self evaluation questionnaires were distributed to all case study teachers at the beginning of first school term in September 1989. The questionnaire were completed by the case study teachers after completing every unit of the teaching packages. Since it was not possible to get the case study teachers from the three research schools together on a regular basis, the completed questionnaires were used to share experiences among these teachers during the trialling work.

4.5.4 Action Research Development and Trialling of the New Science for All Curriculum Material

The action research component of this study comprised development and trialling of teaching packages on the new Science for All curriculum in the three research schools.

* Inservice Programme to Develop Teaching Packages

The action research phase of this study commenced with a two-weeks inservice training programme which was organised by the researcher 14-25 August, 1989 during the summer vacation. The purpose was to develop the ideas (rationale, aims and objectives) of the proposed junior secondary school general science curriculum designed by the researcher. All eight participating teachers took part in the exercise. The venue was at the Bo Government secondary school library.

The main objectives of the inservice training were to enable participating teachers :

1. To reflect on the contextual/organizational factors (as derived from case study findings) that militate against the teaching and learning of General Science for better understanding and meaningfulness for Sierra Leonean students.
2. To interact with the researcher's ideas to identify aims, objectives and content of General Science (using the Science for All ideas) that are in sympathy with Sierra Leonean students' needs.
3. To prepare teaching packages on selected topics for trial that incorporated ideas in Objective 2 .

These objectives were pursued under two main themes: (1) introducing the participating teachers to the ideas of the proposed curriculum, and (2) collaboratively working with these teachers to select content of the new curriculum, and develop a teaching package from that content for trial. Details of these two themes are given in the following section.

[a] Introducing Participating Teachers to the Ideas of the
Proposed Science Curriculum Model

Although case study teachers knew about the trialling of a new curriculum from the start of the project, it was not until the inservice training that these teachers received much in the way of details. This was done through a series of group discussions during the first week of the inservice training. During these sessions, the researcher presented working papers which were followed by group discussions.

At the beginning of the inservice training, the participating teachers were divided into two groups. At the end of every working paper presentation, a short discussion followed wherein questions or observations were welcomed from the participants. After every two working papers, the two groups met separately to deliberate on key issues that were raised in the working papers. To focus the group discussions on themes, the researcher usually asked the participants to react to the main ideas that were contained in the working papers with a view to relating these ideas to the Sierra Leonean situation.

Individual group presentations were made after these discussions. During those presentations the researcher played the role of a moderator. Consensus on main ideas from these discussions which were considered relevant to the Sierra Leonean situation were recorded by Head of the Science Department at Bo government secondary school, who acted as secretary for the inservice training.

Proceedings of the working papers presented and the subsequent group discussions were audio recorded, and important points from these tapes extracted by the secretary. His summary of the inservice proceedings on the working paper presentations and group discussions is included as APPENDIX 4.9. Examples of working papers presented during the inservice training include the following:

- * *Secondary School General Science Curriculum in Sierra Leone: State of the Art from the Science Teachers' Perspective.*
- * *Role of Science Education in Developing Countries.*

- * *The Scientific Knowledge/cultural Interface: Implications for Science Education in Non- western Countries.*
- * *The Dilemma of Relevance in Science Education and Guidelines for Determining Aims, Objectives and Content of General Science Curriculum in Developing Countries.*
- * *The Constructivist View of Learning Science and Learning as a Conceptual Change.*

The first topic was the summary of the case study interview results obtained from the science teachers. The rest of the topics were derived from material which the researcher covered in compiling the Literature Review chapters (Chapters 2 and 3) for the present study, and were aimed at familiarising the participating teachers with the main ideas of the proposed curriculum. The outcome of deliberations on these working papers led to modifications to the aims and objectives of the proposed curriculum that were initially identified by the researcher.

[b] Selection of Content, and Development of Teaching Packages for Trial

The second week of the inservice training consisted of group work aimed at selecting content for the new curriculum, and developing teaching packages on two topics selected from that content for trial. The initial model of the proposed curriculum did not include content since it was the researcher's intention to allow local teachers to determine what they considered to be important topics for their students. In line with the Science for All philosophy, the participating teachers were reminded to select content which has personal and social relevance to the learners. And the teaching and learning of such content should be an extension of what the students already know about their real world. The content of the new curriculum is shown in APPENDIX 3.1

To transform the ideas of the proposed curriculum into a teaching framework, the participating teachers together with the researcher developed teaching packages on two of the topics selected from the new curriculum content for trial. Because of difficulties encountered by many General Science teachers to teach Physics topics, it was agreed that the two teaching packages be prepared for teaching the physics component of a new General Science syllabus at the Forms 1 and 2

levels. Teaching packages on Measurement for Form 1, and Force for Form 2, were developed for trial. Details of the teaching packages are given in Chapter Seven which describes the action research developmental and trialling of the new curriculum material.

* The Trialling of the Teaching Packages

As shown in FIGURE 4.4, the trialling of the teaching packages from the new curriculum was conducted during the first school term of the 1989/90 school year. It involved all eight case study teachers (five participating in teaching of the packages while the three Heads of Departments helped with evaluation of the new curriculum). In addition, the researcher taught the package on Measurement to Form 1 students in the third research school at Gerihun. The decision to participate in the actual teaching was to provide the researcher with first hand experience on implementation of the new curriculum material. The other package on Force for Form 2 was taught by the only case study and General Science teacher at Gerihun secondary school.

In the other two research schools, each case study teacher was assigned two streams each of the same Form. This was to facilitate trialling and retrialling (if necessary) of units of the teaching packages on different streams of students by the same teacher. The packages on Measurement and Force were taught to the 02 and 03 streams of Forms 1 and 2 students at the Bo government secondary school by Albert Yanguba and John Moriba respectively. At the St. Andrews secondary school, Unisa Turay taught the package on Measurement to Form 1 student in the Green and the Blue stream. The package on Force was taught to Form 2 Green and Blue streams of students by Joseph Sandi.

The remaining Forms 1 and 2 streams at both the Bo government and the St. Andrews secondary schools were assigned to other General Science teachers who up to that time had not participated in the study. From the Bo government secondary school, the new group consisted of one teacher teaching the package on Force in Form 201 and another teaching Measurement in Forms 101 and 104. At the St. Andrews secondary school, one teacher taught the package on Force in Form 2 White and Yellow, while the Form 1 White and Yellow streams were taught the

package on Measurement by another teacher. It was hoped that the newly incorporated teachers would act as neutral evaluators of the new curriculum.

4.6 ANALYSIS OF DATA

The data in this study were both qualitative and quantitative. Information obtained from science teachers during the case study and action research phases were all qualitative in nature, while that obtained concerning the attitudes to science survey was quantitative. The sections following provide more details on data treatment.

4.6.1 Treatment of the Qualitative Data

Qualitative data were analysed following Grounded Theory/Qualitative research procedures (see for example Glaser and Strauss, 1967; Bogdan and Biklen, 1982). Recordings of all interviews were transcribed. Important information from those transcripts was collated with other information either from the researcher's field notes on classroom observations or from the teachers' self-evaluation questionnaire. Such information provided tentative answers to Research Questions 2 and 3. A draft format of answers to these questions was presented to the participating teachers during group meetings either in the case study or action research phases for the reasons explained earlier (see 4.5.2 p.72).

4.6.2 Treatment of the Quantitative Data

Students' responses (n=806, and n=322) to the attitudes to science survey questionnaire were scored following the technique described by Fraser (1981). The 70 item statements consisted of 35 negative and 35 positive statements. Negative item responses SA, A, N, D, SD were scored 1, 2, 3, 4, 5. Positive item responses SA, A, N, D, SD were scored 5, 4, 3, 2, 1. Omitted or incorrectly answered items were given a score of 3. The minimum and maximum scores for any of the seven scales were 10 and 50 respectively.

Group mean scores for the nine sample schools were computed for each of the seven scales using the SPSS computer program. A comparison of the results for the nine school sample was carried out in two stages. First, a one-way MANOVA for all seven sub-scales taken together was computed to identify whether or not there was any significant difference among the schools. If this procedure did reveal such difference, a series of one-way ANOVAS was conducted, one for each subscale across schools to identify whether or not there was significant differences among the schools for the given scales. In turn, identification of such difference led to the application of Student Newman-Keuls t test comparisons to trace the source of such difference.

The second stage concerned three sets of variables: Form level (1 and 2), gender (male and female), and type of school (single sex boys or girls, and co-educational). A 2*2*2 multivariate MANOVA for all seven subscales taken together was applied to determine whether or not there were any significant main effects. The SPSSX programme did not 'pool' all three variables, but treated these separately. Thus the programme produced a MANOVA across all seven subscales for Form level, type of school and gender. Significant main effects for MANOVAS were analyzed further for interaction effects using a MANOVA (for Form level, type of school and gender). Significant results here were subjected to ANOVAS for each sub-scale, with significant differences leading to the application of Student Newman-Keuls t test to identify the source of difference. Similar approaches were employed in analysing the pre- and post-tests data for the variable time, class streams and school. The raw data for both the large and the pre and post-testing surveys are shown in APPENDICES 4.10 and 4.11 respectively.

The procedures described above are summarised in FIGURE 4.5.

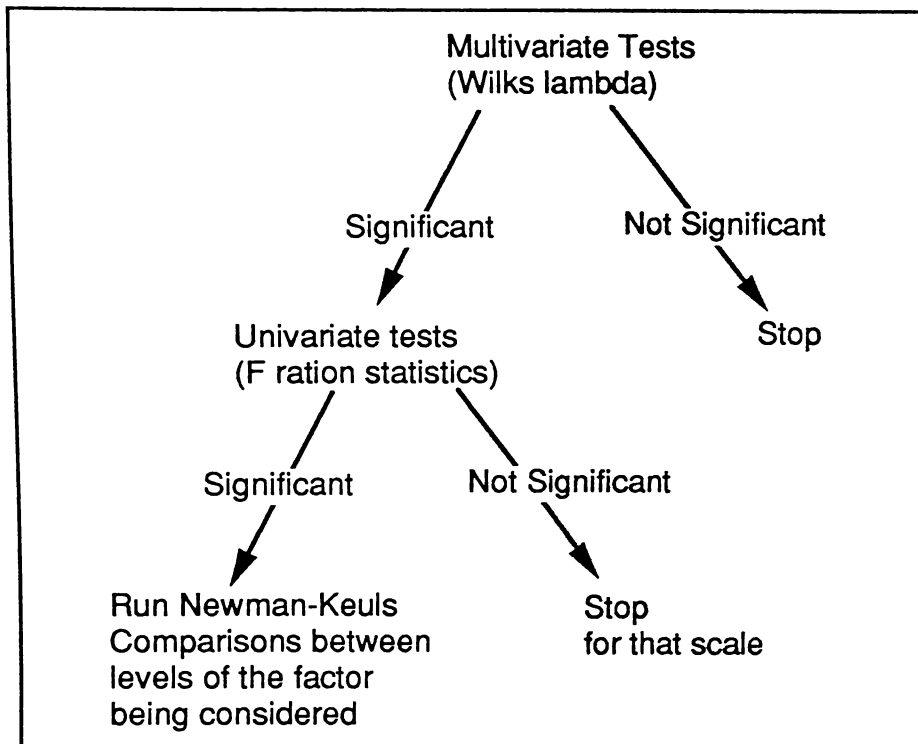


Figure 4.5: Flow Chart for the Treatment of Quantitative Data

**CHAPTER 5: RESULTS: LARGE SAMPLE SURVEY ON STUDENT
ATTITUDES TO SCIENCE**

This chapter discusses the research findings related to Research Question 1 which was as follows:

Research Question 1:

What are the attitudes of junior secondary school students in Sierra Leone towards science?

As discussed in the previous chapter, an answer to this research question was attempted by administering attitude to science questionnaires to a large sample of 806 students. The subscales in this questionnaire were as follows:

1. Application of knowledge of school science in everyday life.
2. Understanding of the nature of science.
3. Attitudes to inquiry.
4. Adoption of scientific attitudes.
5. Enjoyment of science lessons.
6. Leisure interest in science.
7. Career interest in science.

Although the large sample could not be representative of all Sierra Leonean students at the junior secondary school level, performances on these scales would provide a picture of student attitude to science in the Provincial Headquarter towns. Results and discussion are reported first of all for a comparison of the nine schools involved, and then for comparison of responses when the factors form level, type of school, and gender were taken into account.

5.1 THE NINE SCHOOLS

The MANOVA for all seven subscales in the questionnaire taken together was significant (Wilks lambda $p \leq 0.01$, see APPENDIX 5.1). The ANOVAS that followed indicated significant differences for all seven scales ($p \leq 0.01$, see APPENDIX 5.2). Student Newman-Keuls (SNK) tests were used to locate the sources of differences among schools on each significant subscale. The results are summarized in TABLE 5.1 which shows the mean scores for each of the nine participating schools, as well as the mean scores for all schools taken together. The mean scores for all the schools taken together were computed using the raw score of the entire sample ($n=806$) for each of the subscales.

In addition to listing school means for each subscale, TABLE 5.1 also shows significant differences between schools on these subscales by assigning a different index number to each mean. Thus, using the subscale Application of Scientific Knowledge row, significant differences occur between School 1 and Schools 2, 6 and 7; and between School 2 and Schools 1, 3, 4, 5, 8 and 9 etc. On the other hand, there is no significant difference between Schools 1, 3, 4, 5, 8 and 9; or between Schools 2, 6 and 7. All significantly different SNK comparisons in this report have a critical probability of $p \leq 0.05$.

As shown in TABLE 5.1, school means across all attitude scales ranged from 23.0 to 27.2. Two scales only: Attitudes to Inquiry ($\bar{X}=27.2$) and Understanding of the Nature of Science ($\bar{X}=25.4$) produced means above 25.0, but not substantially so. It should be noted that results for Understanding of the Nature of Science scale are questionable because item statements for this scale displayed a low internal coefficient of reliability (see 4.5.1, p.66). Group means for the Application of Scientific Knowledge and Adoption of Scientific Attitudes scales were 24.1 in both cases. The lowest group means were recorded for the Enjoyment of Science Lessons ($\bar{X}=23.1$), Leisure Interest in Science ($\bar{X}=23.0$) and Career Interest in Science ($\bar{X}=23.5$).

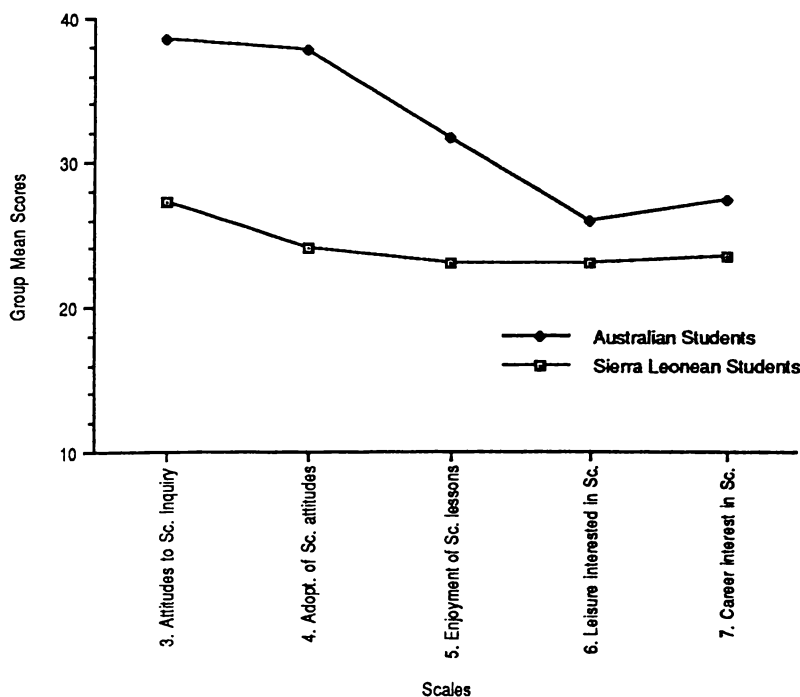
TABLE 5.1 Group Mean Scores Between the Nine Sample Schools for the Large Survey (n=806)

SCALE	S C H O O L									All School Mean (N = 805)
	1 (N = 88)	2 (N = 79)	3 (N = 82)	4 (N = 88)	5 (N = 72)	6 (N = 120)	7 (N = 125)	8 (N = 83)	9 (N = 68)	
Application of Scientific Knowledge	23.8 ¹	25.3 ²	24.0 ¹	24.0 ¹	23.3 ¹	25.3 ²	25.7 ²	22.0 ¹	22.3 ¹	24.1
Understanding of Nature of Science	25.9 ²	25.9 ²	23.1 ¹	26.0 ²	26.5 ²	25.9 ²	26.2 ²	24.2 ¹	24.0 ¹	25.4
Attitude to Inquiry	25.0 ¹	25.4 ²	27.3 ²	27.8 ²	27.2 ²	28.9 ²	28.8 ²	25.4 ¹	24.3 ¹	27.2
Adoption of Scientific Attitudes	22.8 ¹	25.1 ²	24.0 ¹	24.5 ²	23.6 ¹	24.8 ²	26.0 ²	22.7 ¹	21.9 ¹	24.1
Enjoyment of Science Lessons	21.1 ¹	24.5 ²	23.1 ¹	22.9 ¹	23.5 ¹	22.8 ¹	24.4 ²	21.8 ¹	23.8 ¹	23.1
Leisure Interest in Science	21.6 ¹	24.2 ²	23.1 ²	23.4 ²	22.0 ¹	24.0 ²	23.7 ²	20.6 ¹	24.0 ²	23.0
Career Interest in Science	22.2 ¹	25.5 ²	23.0 ¹	22.8 ¹	23.3 ¹	23.6 ¹	23.7 ¹	22.0 ¹	26.2 ²	23.5

Note: Group means carrying different index numbers are significantly different by student Newman-Keuls ($P \leq 0.01$)

In order not to make absolute interpretations of the mean scores - a point Fraser (1981) cautioned about in handling mean scores for science attitudes scales - the school means for the Sierra Leonean students were plotted alongside mean score profiles for Australian students on five corresponding subscales. The Australian mean scores were obtained from 1337 junior secondary school students (Year 7-10) during the field testing of the original TOSRA instrument (see Fraser, 1981, p.7).

It will be recalled that five of the seven scales on the science attitudes questionnaire that were employed in the present study were derived from the original TOSRA instrument (see 4.5.1, p...). Results of the principal components analysis which was conducted on test answers for the 806 Sierra Leonean students revealed a factor structure which corresponded closely to that of the original TOSRA scales. In particular, scales 3, 5, 6 and 7 which were four of the subscales used for the comparison were especially similar (see TABLE 4.2 and APPENDIX 4.7). This indicated that the items developed in Australia had similar meanings for Sierra Leonean students and justified a comparison of the mean scores for the two groups. The profiles for both the Sierra Leonean and Australian students are shown in FIGURE 5.1.



**FIGURE 5.1 Profiles of Group Mean Scores
for Australian and Sierra Leonean Students**

FIGURE 5.1 shows clearly that means across all of the five attitude scales were lower for the Sierra Leonean students. This suggests that junior secondary school students in Sierra Leone exhibit less positive attitudes towards science compared to junior secondary school students in Australia. The differences in mean scores for the two groups were remarkably distinct for the Attitudes to Inquiry, Adoption of Scientific Attitudes, and Enjoyment of Science Lesson scales. On each of these scales, the Australian students had higher means than the Sierra Leonean students with a margin of at least 10.0. The margin between mean scores for the two groups was not great for the Leisure and Career Interests in Science scales, the margin being about 5.

Differences in attitudes towards science between Western and non-Western students have been reported by other researchers. Novick and Duvdvani (1976) reported differences in the attitudes of grade ten students in Israel, depending on the cultural background of the students: those of western extraction displayed more positive attitudes. Jegede and Fraser (1989) established a positive correlation between socio-cultural factors and students' attitudes towards science. They argued that the negative attitudes which children in non-western countries manifest towards science might be a result of inhibitory effect of the socio-cultural factors.

It is possible, therefore, that the wide margin in ranges between mean scores for the Sierra Leonean and Australian students on the Attitudes to Inquiry and Adoption of Scientific Attitudes scales in particular, could be attributed to traditional children's outlook on ways of acquiring knowledge. That Sierra Leonean students had lower mean scores on these scales justified claims that traditional children prefer ready-made solutions in solving new problems. On the other hand, the relatively lower mean scores for the Sierra Leonean students on the Enjoyment of Science Lessons scale may be due to the alienating nature of school science to traditional students. Even though the alienating nature of school science can be argued to be a universal problem, the situation is acute for traditional students for whom science is taught quite devoid of their real world experiences using unfamiliar examples.

The comparable mean scores for the two groups on the Leisure and Career Interests in Science scales might be a consequence of a drop in

students' career interests in science-related disciplines in western countries. Research evidence suggests that the number of students wanting to pursue science related careers in western countries was on the decline in the 1980s (e.g., Galloway, 1990).

FIGURE 5.1 also shows that the range of differences in mean scores between scales for the Australian sample were of substantial magnitude. For example, the range between scales with the highest and lowest mean scores was about 14.0 for this group. The corresponding value for the Sierra Leonean sample was about 4.2. Similarly, the range across the nine schools for the highest and lowest mean scores on each of the seven scales was less than 5 (see TABLE 5.1). Hence, even though the Student Newman-Keuls test ascertained the differences between means for some of the schools on all of the scales as significant, in practical terms these differences may not mean much. In other words, group mean differences between schools on all seven scales were quite marginal.

5.2 COMPARISON OF MEANS BETWEEN FACTORS

Inspection of the results contained in TABLE 5.1 suggests some pattern in mean differences between the coeducational schools (2, 6, 7) and the single sex schools (1, 4, 8 for boys, and 3, 5, 9 for girls) on some of the scales. Similarly, the researcher had the impression that mean scores for Form 1 and 2 in the nine schools were variable. This suggested subjecting the raw data from the nine schools to a series of MANOVA and ANOVA tests using the factors form level, type of school, and gender. The aim was to determine whether these factors had significant main effects on the observed mean differences. Results of these analyses are described in the following sections.

5.2.1 Mean Differences Between Form Levels

Multivariate tests of significance indicated that the factor of form level was significant (Wilks lambda $p \leq 0.05$, see APPENDIX 5.3). The subsequent ANOVAS indicated significant differences for all seven scales ($p \leq 0.05$, see APPENDIX 5.4). Group means for form levels from both single sex and coeducational schools are contained in TABLE 5.2. The table also shows group means for Forms 1 and 2 levels taken together from all nine sample schools. Mean differences between form levels that are significant ($p \leq 0.05$) are indicated in the table.

According to the means displayed in this table, Form 1 students had significantly higher means than Form 2 students on all scales except for the Understanding of the Nature of Science. But, as with the differences in means between schools, the drop rate in means between form level was very marginal, hardly more than a range of 3 on any of the scales.

The tendency for Form 1 students to score higher means than Form 2 students was also evident with the original TOSRA sample. Results for Australian students revealed that the Year 7 students had consistently higher means than the Year 8 students on all of the original TOSRA scales (Fraser, 1981).

A number of studies have reported a decline in attitudes to science with increasing grade level (Ayers and Price, 1975; Yager, 1983; Johnson, 1981). The decline in attitudes in the U.S.A., Johnson (1981) noted, was more rapid among white students than black students. Reporting on a longitudinal study involving the transition of 1000 Scottish students from primary school to secondary school, Hadden and Johnstone (1983) noted:

During the first year of the pupils' exposure to secondary school science, some erosion of initially highly polarized and favourable attitudes to science took place. The evidence suggests that this erosion is more pronounced in science than it is in other subjects (p. 317).

TABLE 5.2 Group Mean Scores Between Form Level

S C A L E	Single Sex		Coeducational		All Schools	
	Form I	Form II	Form I	Form II	Form I	Form II
1. Application of Scientific Knowledge	24.3	22.3	26.5	24.3	25.2 ²	23.0 ¹
2. Understanding Nature of Science	25.5	24.5	26.3	25.7	25.8 ¹	25.0 ¹
3. Attitudes to Inquiry	27.8	24.6	29.3	28.1	28.4 ²	25.9 ¹
4. Adoption of Scientific Attitudes	24.3	22.3	26.0	24.7	24.9 ²	23.2 ¹
5. Enjoyment of Science Lessons	23.5	22.0	25.0	22.1	24.1 ²	22.2 ¹
6. Leisure Interest in Science	23.3	21.7	25.1	22.6	24.0 ²	22.0 ¹
7. Career Interest in Science	23.8	22.6	25.2	22.8	24.3 ²	22.6 ¹

Note: Group means carrying different index numbers are significantly different by Student Newman-Keuls ($p \leq 0.05$)

Despite research findings that show this decline in attitude with increasing grade level, attempts to interpret the decline in Sierra Leonean students towards science with increasing Form level are speculative.

The importance of the role of science and technology for human beings is obvious in all societies. Since very little science is studied in Sierra Leonean primary schools, the high positive attitudes displayed at the Form I levels are likely indications of student interest in learning more about the scientific enterprise. The sudden decline in these students' attitudes may perhaps mean a demonstration of their dissatisfaction with the secondary school science curricula. It is possible that the students' expectation of science is not what the secondary school science curricula are offering.

5.2.2 Mean Differences Between Type of School

The MANOVA for all seven subscales in the questionnaire taken together showed that the factor type of school was significant (Wilks lambda $p \leq 0.01$, see APPENDIX 5.5). The follow-up ANOVA results for this factor (see APPENDIX 5.6) indicated significant differences for all seven scales ($p \leq 0.05$). Student Newman-Keuls tests were used to locate the source of difference among types of schools on each significant subscale. ANOVA analyses were carried out using two ways of categorising the types of schools. Firstly, group means for coeducational schools were compared with means for the single sex schools taken together. Next, the means for the coeducational schools were compared with mean scores for single sex boys' schools and single sex girls' schools (see APPENDIX 5.7). The results for the two analyses are shown in TABLES 5.3 and 5.4 respectively.

TABLE 5.3 shows that mean scores for the coeducational schools were consistently higher than those for the single sex schools, but significantly so on five of the subscales only. TABLE 5.4 further reveals that mean differences between coeducational and single sex boys' schools were significant on six scales. The differences in means between either single sex boys or single sex girls and the coeducational schools were not significant for the Understanding of

TABLE 5.3 Comparison of Mean Scores Between Types of School
(single sex and coeducational schools)

S C A L E	Single Sex (N=482)	Coeducational (N=324)
1. Application of Scientific Knowledge	23.3 ¹	25.2 ²
2. Understanding the Nature of Science	25.0 ¹	26.0 ¹
3. Attitudes to Inquiry	26.2 ¹	28.8 ²
4. Adoption of Scientific Attitudes	23.3 ¹	25.3 ²
5. Enjoyment of Science Lessons	22.7 ¹	23.9 ²
6. Leisure Interests in Science	22.4 ¹	23.9 ²
7. Career Interest in Science	23.1 ¹	24.1 ¹

Note: Group means carrying different index numbers are significantly different by Student Newman-Keuls ($P \leq 0.05$).

the Nature of Science scale. Between coeducational and single sex girls' schools, mean differences were only significant for the Application of Scientific Knowledge, Attitudes to Inquiry, and Adoption of Scientific Attitudes scales. There were no significant differences between means of these two groups on the Enjoyment of Science Lessons and Leisure and Career Interests in Science scales. But both groups had differences in means compared to single sex boys for these three scales. For the Application of Scientific Knowledge, Attitudes to Inquiry and Adoption of Scientific Attitudes scales, there were no significant differences between means for the single sex schools.

TABLE 5.4 Comparison of Means Scores Between Types of Schools
(Single sex boys, single sex girls, and coeducational)

Scale	G R O U P M E A N S		
	Single Sex boys (N=260)	Single Sex girls (N=222)	Co-educational (N=324)
Application of Scientific Knowledge	23.3 ¹	23.2 ¹	25.5 ²
Understanding of Nature of Science	25.4 ¹	24.5 ¹	25.0 ¹
Attitudes to Inquiry	26.0 ¹	26.4 ¹	28.8 ²
Adoption of Scientific Attitudes	23.4 ¹	23.2 ¹	25.3 ²
Enjoyment of Science Lessons	22.0 ¹	23.5 ²	23.4 ²
Leisure Interest in Science	21.9 ¹	23.0 ²	23.9 ²
Career Interest in Science	22.4 ¹	24.0 ²	24.1 ²

Note: Means carrying different index numbers are significantly different by Student Newman-Keuls ($P \leq 0.01$)

Studies of the relationship between school variables such as type of school and attitudes to science seldom occur in the research literature. Most studies involving school variables have compared the relationship between gender differences in science attainment and the type of school attended. Hence, results of the relationship between attitudes to science and type of school from the present study are discussed on a stand-alone basis.

The results show that students in co-educational schools displayed significantly more favourable attitudes towards science than students in single sex boys' schools. The differences in attitudes between the co-educational and the single-sex girls schools were only significant on three of the seven science related attitudes scales. Furthermore, single-sex girls' schools exhibited significant favourable attitudes towards science than the single sex boys' schools on three of the science related scales. However, even though these differences were statistically significant, they are not large enough to warrant a change in educational policy.

5.2.3 Mean Differences for Gender

The MANOVA for all seven subscales taken together indicated that the gender factor was also significant (Wilks lambda $P \leq 0.05$, see APPENDIX 5.8). The ANOVA results for this factor, taken for the categories boys in boys' schools, boys in co-educational schools, girls in girls' schools, and girls in co-educational schools indicated significant differences for all seven scales ($P \leq 0.05$, see APPENDIX 5.9). The ANOVAS for the categories boys and girls showed significant differences for only three out of the seven scales ($P \leq 0.05$, see APPENDIX 5.10). Results of Student Newman-Keuls tests to locate sources of differences among these categories are shown in TABLES 5.5 and 5.6 respectively.

TABLE 5.5 Comparison of Mean Scores for Gender (Across Type of Schools).

SCALE	Boys in Boys Schools (N=260)	Boys in Co- educational Schools (N=164)	Girls in Girls Schools (N=222)	Girls in Co- educational Schools (N=160)
Application of scientific knowledge	23.3 ¹	25.2 ²	23.2 ¹	25.7 ²
Understanding of Nature of Science	24.4 ¹	26.1 ²	24.5 ¹	25.9 ²
Attitudes to Inquiry	26.0 ¹	29.0 ²	26.4 ¹	28.6 ²
Adoption of Scientific Attitudes	23.4 ¹	25.2 ²	23.2 ¹	25.5 ²
Enjoyment of Science Lessons	22.0 ¹	23.4 ²	23.4 ²	24.4 ²
Leisure Interest in Science	21.9 ¹	23.5 ²	23.0 ²	24.3 ²
Career Interest in Science	22.3 ¹	23.7 ²	24.0 ²	24.5 ²

Note: Group means carrying different index numbers are significantly different by Student Newman-Keuls ($P < 0.05$)

TABLE 5.5 shows no significant differences in mean scores between boys and girls in co-educational schools on all seven scales, but mean scores for either group were significantly different from boys in single sex schools on all seven scales. In general, girls in co-educational schools had higher group means than girls in single-sex schools, but the differences were only significant on four of the science related attitudes scales. TABLE 5.6 shows girls had significantly higher means than boys on the Enjoyment of Science Lessons, Leisure Interest in Science and Career Interest in Science scales. But once again, the differences in means between some of the categories, though statistically significant, were marginal in practical terms on all scales. It is important, however, to note that the results suggest that girls manifest more positive attitudes towards science than boys at the junior secondary school level in Sierra Leone.

TABLE 5.6 Comparison of Mean Scores for Gender (Boys and Girls)

S C A L E	Boys (N=423)	Girls (N=383)
1. Application of Scientific Knowledge	24.0 ¹	24.3 ¹
2. Understanding the Nature of Science	25.7 ¹	25.1 ¹
3. Attitudes to Inquiry	27.2 ¹	27.3 ¹
5. Adoption of Scientific Attitudes	24.1 ¹	24.2 ¹
5. Enjoyment of Science Lessons	22.5 ¹	23.9 ²
6. Leisure Interests in Science	22.5 ¹	23.6 ²
7. Career Interest in Science	22.9 ¹	24.3 ²

Note: Group means carrying different index numbers are significantly different by Student Newman-Keuls ($P < 0.05$).

This particular finding does not seem to agree with what is reported in most science education research literature. Studies on students' attitudes to science from North America and Western Europe have reported persistent sex differences in favour of boys. Gardner (1975), in a review of sex differences in achievement, attitudes and personality of science students observed that boys display a considerably more favourable attitude towards science than girls. Other studies which have reported that males have more positive attitudes to science than females include Ato and Wilkinson (1983), Johnson (1981) and Menis (1983).

Some studies, in non-western countries however, have found that girls exhibit more favourable attitudes towards science than boys. To illustrate, Klainin (1984) in a study that investigated the effects of an activity-based curriculum on student outcomes in Chemistry in Thailand, found that girls displayed significantly more favourable attitudes than boys. But unlike her findings which showed that girls in single-sex schools performed better than the other groups, the present study showed that girls in co-educational schools performed better than other groups. Other studies, from western countries have also reported no statistically significant gender differences in attitudes towards science (Ayers and Price, 1975; Hofman, 1977; Selim and Shrigley, 1983). The disparity in opinion on the influence of gender on attitudes to science may be an indication that gender alone is not a significant influence on students' attitudes. It has to be considered alongside other variables. In particular in the present study, gender differences were not apparent in coeducational schools. This suggests that it is an aspect of school culture, not gender experiences *per se* which have resulted in the significant gender effect.

For example, Ormerod and Duckworth (1975) indicated the importance of distinguishing between the physical and biological sciences when sex differences in attitudes to science are considered. Thus, boys are generally more positive towards the physical sciences while girls are more interested in biological and social science topics. The fact that very little physical science is studied at the junior secondary school level in Sierra Leone could well be the reason why girls exhibit more favourable attitudes to science than boys. As a result of the Sierra Leonean General Science teachers' subject specialties (see p.104), topics covered at the junior secondary school science classes were mostly biological.

5.3 INTERACTION BETWEEN FACTORS

Multivariate tests of significance did not indicate significant difference for a three way interaction between the factors form level, type of school and gender. Similarly, there was no significant interaction between effects of gender by form level, type of school by form level, and type of school by gender. Statistical details on these tests are contained in APPENDIX 5.11. In sum, then, even though there

were significant main effects for the factors examined, there were no significant interaction effects for these same factors.

5.4 SUMMARY

Many writers and researchers in the area of attitudinal studies in Africa have stressed the important role that attitudes towards science could play in the technological advancement of African nations (Taiwo, 1981). The range of mean scores obtained in the present study of junior secondary school students in Sierra Leone suggested less positive attitudes towards science than had been reported among Australian students. Since attitudes are thought to influence achievement (Schibeci and Riley, 1983), the less positive Sierra Leonean attitudes do not foretell a bright future for secondary school science in that country. In particular, mean scores were lowest for attributes that measured students' enjoyment of science lessons, leisure and career interests in science.

There was not a large range of scores between the groups in the nine schools. Even though some of the scores were significantly different between schools on all of the seven science-related scales, the overall differences in magnitude were not large enough to warrant a change in educational policy. This was also true for the differences observed between the factors form level, type of school and gender. The observed differences were not large enough to serve as basis of policy recommendation. However, some of the findings of this study were unique and thus need some amplification.

The results showed that girls displayed more favourable attitudes than boys on most of the science-related attitudes scales. In particular, these differences were significant for the Enjoyment of Science Lessons, Leisure and Career Interests in Science scales. Furthermore, in their bids to explain why boys were better achievers in science, some theorists have favoured environmental explanations to explain sex differences in attitude towards science. The Commonwealth Schools Commission (1984), for example, suggested that there may be advantages for girls in single-sex grouping for learning science. Kelly (1978) tested a range of environmental hypotheses, and she found that girls

achieved no better in single-sex girls' schools than in co-educational schools when other important variables were controlled.

Results in the present study showed that students in co-educational schools displayed more positive attitudes towards science than students in single-sex schools. Furthermore, the results showed that girls in co-educational schools displayed more favourable attitudes towards science than girls in single-sex schools. The differences between the two groups were significant on four of the seven science-related attitudes scales. But there was no significant difference in attitudes towards science between boys and girls in co-educational schools, and both groups displayed more positive attitudes towards science than boys in single sex schools. Among the single-sex schools, girls in single-sex schools had significant higher means than boys in single-sex schools on three of the science-related attitudes scales. Finally, the results showed a decline in students' attitudes towards science as they moved from Form 1 to Form II. This is a worrying trend that justifies concerns about curriculum innovations aimed at making science more interesting and meaningful for the majority of learners in the Sierra Leonian school situation.

CHAPTER 6: RESULTS: CASE STUDIES OF SCIENCE TEACHERS

Recent studies show that teachers possess their own theories about what they do - what is reasonable, feasible and possible - in the classroom. It was considered important therefore, that the present study (which was aimed at introducing science teachers to a new curriculum model) commenced by investigating views held by these teachers about the junior secondary school science programme. The views that were sought were demarcated by Research Question 2 which was as follows:

Research Question 2:

In relation to the junior secondary school programme, what are the perceptions of science teachers towards:

- 2.1 curriculum in general science;
- 2.2 the nature of science and ways of acquiring scientific knowledge;
- 2. methods of teaching science;
- 2. the appropriateness of the junior secondary school science for community living?

Sierra Leonean science teachers' perceptions in relation to these questions were ascertained through interviewing, as well as from classroom observations of science lessons by the researcher during the case study phase.

6.1 GENERAL SCIENCE TEACHERS' QUALIFICATIONS AND SUBJECT SPECIALITIES

The poor state of secondary school science education in Africa has often been attributed to the high incidence of untrained science teachers. As part of the researcher's assessment of the status of the junior secondary school science programme in Sierra Leone, information was sought on the qualifications and subject specialities of General Science teachers. The categories of those teachers is given below.

FIGURE 4.3 (p.60) provides a resume of the case study teachers and reveals that 67 percent of general science teachers from the three research schools were trained and qualified. Of the remaining 33 percent, 8 percent were trained but unqualified, and 25 percent untrained and unqualified.

The relatively high incidence of trained and qualified science teachers signals an improvement on Cole's (1970) finding that hardly any graduate teachers were allocated to teach at the junior secondary school level, which made up 75 percent of secondary school population. Such improvement is to be expected considering the time lapse and efforts by the Sierra Leonean government to upgrade the standard of education in that country.

It should be noted, however, that the high percentage of trained and qualified junior secondary science teachers in the three research schools does not reflect the national picture. Trained and qualified teachers are not evenly distributed among secondary schools in Sierra Leone. Since teachers have the option to teach in schools of their choice, the majority prefer to teach in well established schools normally found in big towns like Bo.

For example, of the 2830 trained and qualified secondary school teachers in the 1988/89 school year (see TABLE 6.1), 35 percent of them were teaching in 37 schools in and around Freetown, the capital city. The remaining 65 percent were shared among 168 provincial schools. It is not surprising, therefore, that schools in Bo (the second largest town in the country) to exhibit the high incidence of trained and qualified teachers stated in this report.

TABLE 6.1 Secondary School Teachers Statistics - 1988/89

	No of Schools	No of Tchs.	No of Pupils	No of GQ	No of H.T.C.	No of T.C.	No of 'A' Lev- el	No of 'O' Lev- el	No of CU	Others
<u>EASTERN PROVINCE</u>										
Kailahun District	18	275	7679	52	81	36	11	65	20	22
Konema District	19	406	8897	104	98	25	37	59	53	32
Kono District	16	340	7492	68	84	59	16	47	35	18
Total	53	921	24068	224	263	121	64	171	108	72
<u>SOUTHERN PROVINCE</u>										
Ba District	28	681	13702	200	208	34	40	63	91	42
Bonthe District	6	80	1760	20	21	7	4	11	9	10
McYamba District	16	322	4863	196	80	24	8	48	36	31
Pujehun District	6	87	1219	17	17	13	4	24	10	2
Total	56	1170	21544	433	328	78	56	146	146	85
<u>NORTHERN PROVINCE</u>										
Bo District	20	495	10796	82	161	75	30	68	68	65
Port Loko District	12	245	4756	56	68	19	14	17	38	31
Kambia District	9	151	3478	24	37	23	5	28	17	20
Koinadugu District	5	70	2435	18	18	5	2	14	8	5
Tenkolili District	13	270	5976	50	77	40	6	29	16	50
Total	59	1231	27441	230	361	162	57	156	127	171
<u>WESTERN AREA</u>										
	37	2096	28642	494	497	41	8	42	200	104
Grand Total	205	4945	101695	1381	1449	402	185	515	581	432

SC IRRP: National Census Office, Sierra Leone Government Printing Press.

It should be further noted that 73 percent of science teachers in the three research and seven other schools selected for the large sample attitude survey (see APPENDIX 4.6) were trained and qualified. Though this figure was derived from a very small sample (about 5 percent of the total number of secondary schools in Sierra Leone), it reinforces the claim that the quality of general science teachers is improving.

Further analysis of the information on the 33 general science teachers in the case study schools reveals five major science subject specialities for the qualified as well as the qualified but untrained teachers: Biology, Agriculture, Home Economics, Chemistry and Physics. The untrained and unqualified teachers were not associated with any subject speciality and, for the convenience of making comparisons, their subject speciality was classified as general. The proportion of those six subject specialities is illustrated in FIGURE 6.1 below.

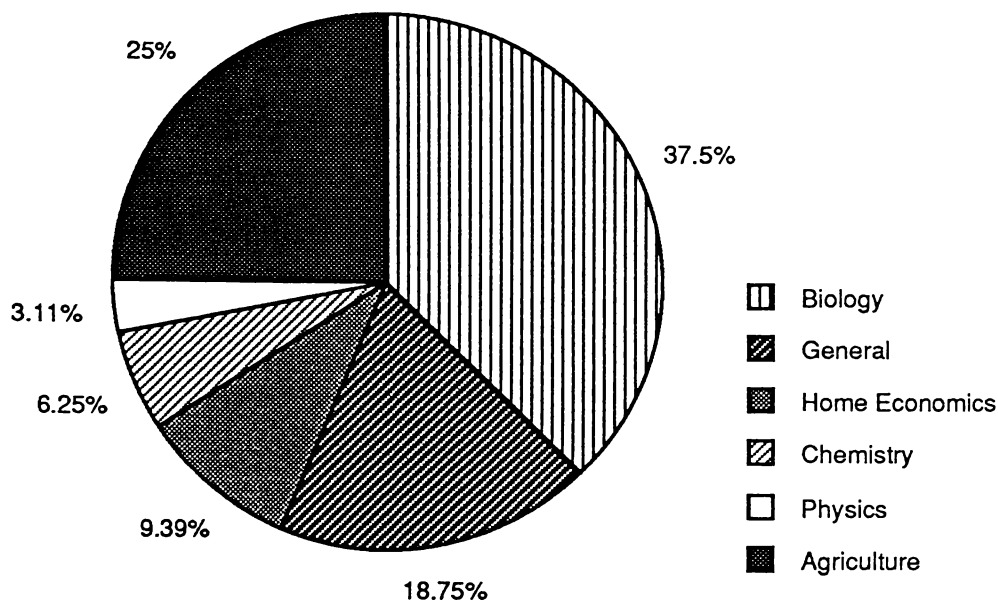


FIGURE 6.1: Subject Specialities for 33 General Science Teachers.

The diagram above shows that biology and agriculture trained teachers constituted about 67 percent of the general science teachers in the ten schools. The untrained and unqualified teachers constituted about 18 percent, followed by teachers with home economics background. Least represented were teachers with background in the physical sciences. Both chemistry and physics specialist teachers constituted about 6 and 3 percent respectively.

To summarize, while the quality of General Science teachers in terms of qualifications seems to be improving, the subject speciality of these teachers poses a source of concern, especially the low number of teachers with background in the physical sciences.

6.2 SCIENCE TEACHERS' PERCEPTIONS OF THE GENERAL SCIENCE CURRICULUM

Teachers are the interpreters of curriculum. Hence, science teachers' perceptions about the existing junior secondary school curriculum was believed by the researcher to be a vital starting point for the present study. The results of that investigation is presented in the following sections. The findings are presented under two sections: science teachers' perceived aims and objectives for the general science curriculum (6.3.1 below); and these teachers' perceptions of the content of the general science curriculum (6.3.2 below).

6.2.1 Aims and Objectives for The General Science Curriculum

There was no concensus among science teachers on the aims and objectives of the General Science curriculum. This was probably due to the lack of a national curriculum. A synopsis of the participating teachers' views about aims and objectives for science at the junior secondary school level is as follows:

1. To introduce students to topics contained in the ordinary level General Certificate Examination syllabus.
2. To teach students the basic definitions in Chemistry, Physics and Biology.
3. To prepare students for further studies in science.
4. To familiarise students with laboratory instrumentation.
5. To help students appreciate the technological world.
6. To help students develop interest in science.

* Introducing Students to Topics in the G.C.E. 'O' Level Syllabus

The researcher was told that the aim of secondary school education to most Sierra Leoneans is to nurture students capable of passing five or more subjects in the 'O' level General Certificate of Examination (G.C.E.). The five or more G.C.E. 'O' level passes is a prerequisite for gaining entrance to tertiary institutions which is the dream of every school-going Sierra Leonean child.

To fulfil these expectations, teachers, under the instruction of school administrators, have narrowed down the aims of the five year secondary school education to preparing students solely for the purpose of passing the G.C.E. examination. Consequently, it was stressed by the participating teachers that one of the aims of the general science curriculum was to introduce students to topics contained in the G.C.E. 'O' level science syllabus.

To illustrate the extent to which the G.C.E. 'O' level examination influences the secondary school curriculum, one teacher stated that teachers in all subjects were teaching purely for the purpose of preparing students towards the 'O' level examination. A Physics teacher and Head of a Science Department in one of the research schools explained:

The G.C.E. 'O' level syllabus is a two year course starting at Form 4. We try to bring it down as far as Form 1 since there are certain topics in the syllabus which can be taught in simplified form at the junior secondary school level. Examples of such topics are expansion, heat transfer and different ways of heat transfer.

With this type of emphasis, it was surprising to learn that all participating teachers knew that between 40 to 45 percent of students in general science do not reach Form 5. Asked what purpose this group of students would have in studying general science, one teacher replied:

Honestly no provision is made for them. Teachers do not consider drop-outs. What we are interested in is teaching these students and giving them examinations. Those who pass are okay and those who fail we completely forget about.

So, even though this particular objective was stressed by all the participating teachers, it turned out to be unattainable for a majority of students who study general science at the junior secondary school level.

* Teaching Students Basic Definitions in Science

As another important objective, teachers believed that general science at the junior secondary school level should be teaching students basic definitions in Physics, Biology and Chemistry. The researcher's classroom observations showed that these definitions were often taught by being derived directly from 'O' level textbooks, and written on chalkboards or dictated to students. There was hardly any effort on the part of teachers to simplify those definitions. The reason, according to one teacher, was that definitions do not change. He explained:

If one defines heat as a form of energy, that definition remains valid all throughout the secondary school education. Such that a Sixth Form student will give the same definition of heat as a Third Form student would

Although not explicitly stated, the expected learning outcome following this specific objective appeared to be nothing more than telling students the names of concepts or processes contained in science textbooks. It was not apparent from classroom observations whether students' understanding of these concepts or processes was considered important by the teachers. The teachers' purpose seemed to be telling students about as many processes as were outlined in the syllabuses. In one of the observed lessons, the particular teacher covered topics on energy, work, power and machines during one 80 minutes session!

* Preparing Students for Future Studies in Science

Science teachers believed, too, that general science should prepare students for future studies in science. The preparation should entail teaching students the basic skills of observing, collecting, recording and interpreting of data, and drawing conclusions based on data. Development of these skills, according to the teachers, could best be promoted by involving students in practical activities.

Yet the researcher's classroom observations did not reveal many practical activities in science lessons at the junior secondary school level. The few practical lessons that were observed were laboratory exercises or 'rituals' in which students were given specific procedures to follow.

* Familiarising Students with Laboratory Equipment

Consistent with their faith in practical activities, science teachers believed laboratory exercises are effective in increasing students' processing skills and positively influencing their attitudes. Hence, as another objective, teachers believed the science programme in Forms 1 and 2 should familiarise students with the laboratory equipment they would be using in senior science classes. These familiarisations were mostly done diagrammatically on chalkboards or through demonstrations, with the teachers displaying instruments to the students. Encouraging students to have first hand experiences with those instruments was seldom seen.

* Helping Students Appreciate the Technological World

Science teachers believed that the study of general science should enable students to appreciate the technological world in which they live. By studying science, teachers expected students to appreciate modern machines like videos, microwave ovens and radio transmitters.

These examples show that technology was being perceived from the point of view of the modern world. None of the teachers linked the teaching and learning of General Science to the indigeneous technology that abounds in the students' environment. Even with reference to modern technology, there was no evidence of relating what was taught in General Science lessons to the understanding of that technology in the contemporary world.

* Helping Students Develop Interest in Science

As another important objective, science teachers believed that the study of General Science should enable students to develop interest in science later in life. This interest, they believed, could be nurtured through activity-oriented General Science lessons. This idea was once again not practised by the teachers in their everyday teaching. Most General Science lessons were very didactic and the learning exercises ended with the formal class lesson. There were no instances wherein students were engaged in out-of-school science learning activities, apart from the normal textbook orientated assignments.

It was apparent from interviews and classroom observations that most of what the science teachers enumerated as aims and objectives of the General Science curriculum was only lip service. Their aims and objectives were simply examples of those found in standard textbooks. The entire teaching and learning of general science was centred around one theme, that of preparing students for the 'O' level school certificate examination.

Of special interest to the researcher was the failure by the science teachers to perceive of aims and objectives for General Science that had immediate benefits to the learners or their communities. The goal of studying general science was to prepare students for further studies in the sciences. This 'investment outlook' had no real dividends for students who did not continue with the study of science beyond the junior secondary school level. Consideration of what constituted the content of a curriculum based on such aims and objectives is addressed in the next section.

6.2.2 The Content of the General Science Curriculum

The participating teachers reported the following criteria for the topics in the General Science syllabuses:

1. Topics selected from the G.C.E. 'O' level certificate examination syllabus.

2. Topics selected directly from recommended textbooks.
3. Topics from the above two sources adapted to suit science teachers' subject specialities.

The above three criteria (detailed in the following section) were by no means hierarchically, or uniformly, adhered to in all of the schools.

* Topics Selected from the G.C.E. 'O' Level Examination Syllabus

Teachers reported that schools' reputations were determined by the number of successful candidates the school could produce in the certificate examinations.

Parents and students, likewise, look for schools producing high percentage passes in 'O' level examinations. Principals of secondary schools, in turn, advocate teaching content which is attuned to the G.C.E. 'O' level syllabus. The idea of the syllabus as a guarantee of success in examinations was observed by Cole (1970):

The belief that the syllabus is a sure guideline to success in an examination is sufficiently strong in the minds of students that a teacher who deviates from the syllabus in order to innovate is met with strong students' opposition (p.12).

This belief has not changed over the last twenty years. If anything, the content that is directed by the examination is becoming more firmly rooted within the educational system in Sierra Leone. When asked whether selection of content in the General Science syllabus takes into consideration topics not contained in the 'O' level syllabus but are important in students lives, one teacher emphatically replied:

No, I strictly follow the G.C.E. 'O' level syllabus, preparing students directly towards passing the 'O' level examination.

The reason, according to a colleague, was that *"society is looking out for better results, rather than what students can do"*.

* Topics Selected from Textbooks

In addition to the examinations, another factor which influenced the content of the General Science syllabuses was the kind of textbooks available in a particular school.

Two sets of books were commonly used as recommended texts for General Science in most schools. These were General Science for Tropical Schools, Volumes One and Two by F. Daniel, and Everyday Science for the Tropics by Gotman and Hobson. The former, which was the more popular of the two, was first published in 1940 with the latest edition in 1966. Apart from its out-datedness, the content of most of the topics in the text is developed using examples not familiar to students.

The science teachers' dependence on textbooks as a source of scientific knowledge was all-pervading. Teaching measurement to Form 1 students, for example, was done by strictly following the format of the recommended textbooks. The teachers appeared to be helpless in the absence of textbooks to prepare teaching units, even at Form 1 level.

* Teachers' Subject Speciality Influenced Topics

Of the three factors identified as those influencing the content of the General Science curriculum, teachers' subject speciality turned out to be the most dominant. Even in situations where principals would want content selected from either the 'O' level syllabus or a recommended text, it was reported that science teachers often selected content mainly on the basis of their subject speciality. So severe was this bias that one teacher described the previous General Science syllabus in his school as a course in "Nature Study" since it was compiled by teachers whose backgrounds were in Biology and Agriculture.

6.3 SCIENCE TEACHERS' PERCEPTIONS OF THE NATURE OF SCIENCE AND WAYS OF ACQUIRING SCIENTIFIC KNOWLEDGE

Ideally, the view of science presented to children by teachers, or directly through curriculum material, will closely relate to scientist's science. However, it is believed that teachers undoubtedly have a wide variety of viewpoints, ranging from almost child-like science to scientists' science. The case for Sierra Leonean teachers is highlighted below.

Scientific knowledge according to some of the teachers *"is static or unchangeable"* because *"scientific definitions or mathematical relations describing scientific processes are the same all over the world and do not change"*. Thus the main source of scientific knowledge was from textbooks. Indeed, the teachers' perceptions about ways students acquire scientific knowledge was through a process that one teacher described as *"giving students facts derived from textbooks"*. Even the few teachers who believed that scientific knowledge is relative, supported the idea of presenting scientific knowledge as an absolute truth to students at junior secondary school level. The above pronouncements tantamount to the traditional cultural transmission approach encapsulated in a quote from Hutchins (1936) as follows:

Education implies teaching. Teaching implies knowledge. Knowledge is truth. The truth is everywhere the same. Hence education should be everywhere the same.

(Source Pope and Scott, 1983, p.4)

Invariably, it was their understanding of ways of acquiring scientific knowledge that influenced the method that these teachers deployed to teach General Science.

6.4 SCIENCE TEACHERS' PERCEPTIONS OF THE METHODS OF TEACHING SCIENCE

The strong tendency for these teachers to fill students' empty minds with scientific facts was demonstrated in classrooms by employing teaching methods which they described as 'chalk and talk'. This entailed the teacher standing in front of students in straight rows of

desks writing notes on the chalkboard, sometimes offering explanations between notes. While almost all of the case study teachers proclaimed the process method as a better way of acquiring scientific knowledge, and some seemed knowledgeable about elements in inquiry/discovery teaching techniques, classroom observations revealed that their teaching methods were didactic and "chalk and talk" orientated.

It is possible that these teachers came across the process (inquiry/discovery) method of teaching science during their preservice training without really becoming committed to the underlying ideology of this approach. Lending support to this proposition, one teacher reported that they were taught many "ideal methods" of teaching science during their preservice training programmes, and he lamented that they had hardly ever tried these methods in real classroom situations. Teachers cited the following as some of the factors that inhibited the deployment of those 'ideal' teaching methods:

1. Examination consciousness.
2. Lack of motivation in the teaching profession.
3. Inadequate time and facilities to do the job.

With respect to the first factor, the high premium placed on public examinations means that teaching timetables and syllabuses are 'dished out' to science teachers as directives to be completed within specified times. Failure to complete an assigned syllabus often leads to the teacher being reprimanded. To ensure that teachers complete the prescribed syllabus, it was reported to the present researcher that some principals ask teachers to draw up examination questions covering the entire syllabus well ahead of the examination time. Demands such as these, coupled with the generally poor conditions of service, have left science teachers with no alternative but to dash through the syllabus using the fastest means of teaching which is the 'chalk and talk' method. Even those teachers who professed some inclination towards the process method described their teaching using phrases such as:

We tell students that science is something concerned with finding out about things (Teacher 1). When I was teaching about hardness of water, I told students the differences between soft and hard water (Teacher 2). In practicals, we tell students exactly what to do and what to expect (Teacher 3).

Teaching by giving out facts or telling students about the processes of science indicated the teachers' theoretical position on the nature of science and ways of acquiring scientific knowledge. From the classroom observation, evidence emerged suggesting that these teachers unconsciously practised teaching methods very much attuned in the Baconian tradition.

For most of the time, teachers presented scientific knowledge to students as finished facts contained in textbooks. Even with familiar topics, only textbook examples were highlighted. Student contributions unless related directly to textbook material, were ignored.

In one lesson on how to evaporate a saturated solution to dryness, the teacher asked students to name some apparatus that they would need to carry out the task. One of the students shouted "A pot". That example was ignored by the teacher who eventually listed the following as the necessary equipment: test tube, fire, filter paper, funnel, sand bath etc. The teacher failed to realise that separation of solutes from solvents is a common everyday activity in most students' homes in soap making, extraction of salt etc. In all these examples the people use pots as the main apparatus.

Furthermore, either from ideas borrowed from international textbooks or anecdotes still remembered from their preservice training, teachers emphasised the importance of experimentation as a process of learning science. However, their idea of experimentation ("*telling the students exactly what to do and what to expect*") is similar to what Tobin, Espinet, Byrd and Adams (1988) describe as the cook book type. It is a routine of engaging students in collecting data that makes little or no sense to them. It is obvious, therefore, that the purpose of experimentation for those teachers was not to inculcate the virtues of good scientists in the students. Rather, a ritual was gone through which is part of the empiricist - inductivist Baconian outlook on the process of science, consisting among other things of observation, experimentation and verification.

Another classroom behaviour of general science teachers that lends support to their empiricist conviction was their frequent use of mathematical representations. In most general science physics lessons

in particular, teachers spent about 80 percent of the teaching time solving mathematical problems or deriving mathematical formulae. In teaching units on measurement in Form 1, more time was spent on solving mathematical problems involving conversion from one unit to another than actually involving students in measuring activities. APPENDIX 6.1 exemplifies a typical 80 minutes lesson plan on Measurement for Form 1 students prepared by one of the case study teachers. This type of mathematical problem solving was aimed at teaching an algorithm, and once mastered there were no cognitive demands on students to solve similar problems.

6.5 SCIENCE TEACHERS' EVALUATIONS OF THE APPROPRIATENESS OF THE JUNIOR SECONDARY SCHOOL SCIENCE FOR COMMUNITY LIVING

Given the realities of their teaching approach described above, science teachers nevertheless recognized that the junior secondary school science programme was "too academic" and that its main purpose was to spoon feed students with facts for memorization and passing examinations. The teachers seemed to recognize, too, that students did not see knowledge of school science as something they could apply to everyday problems. One teacher described students' outlook on secondary school science as:

Another world with lots of experimentation, lots of mathematics, lots of complicated ideas, all of which are not part of their everyday life.

This alienating of the science education programme from everyday life was bound to continue according to one teacher educator in science:

As long as science teachers believe that science or learning in general is acquisition of knowledge extracted from textbooks written for developed countries, ignoring what exists in their own environment.

It was definitely a consequence of the premium placed on public examinations, and most teachers saw this as devastating. Teachers reported that school dropouts who returned to their villages showed no evidence of having learned any science at school. One of the teachers elaborated thus:

Looking at it very closely, one of the reasons people in the villages (non-school goers) make a mockery of western education is the inability of school dropouts to exhibit evidence of being different from those who had not been to school. This holds true for science. School dropouts cannot apply knowledge of the science they learn at school to distinguish between their outlook to life from the non school goers

Even in the school setting the science programme failed to motivate students to take on further studies in science because the number of students studying science diminished with ascending seniority at school (especially for the physical sciences). Science teachers attributed this to the negative attitudes of students towards science which had three underlying influences: the action of some general science teachers; students' bias about the subject; and societal values that militate against the propagation of school science ideas.

That General Science teachers concentrated on topics related to their subject specialities, was identified by teachers as one of the factors responsible for students developing negative attitudes towards science. Because very few General Science teachers had a physical science background, topics in physical science were hardly taught in Form 1 and 2 General Science lessons in most schools. Some case study teachers confessed neglecting topics in Physics in particular because they felt uncomfortable handling those topics. Very little Chemistry, and at times no Physics topics, are taught until Form 3 where preparation for the G.C.E. 'O' level examination commences. The ultimate effect of this neglect, the teachers believed, was student resentment of these subjects. Teachers reported that students study Chemistry and Physics at the senior secondary school level only when they are compulsory requirements for tertiary courses that the students would want to pursue. One teacher attributed the low numbers of students studying physics at senior secondary school level or tertiary institutions to this neglect.

Quite apart from the resentment arising from the poor foundation in the physical sciences, the teachers reported that some of their colleagues inadvertently portray an image of science to students as a difficult subject. "*Setting difficult examination questions to impress upon students that science is a difficult subject*" was the teachers' description of the action of some of their colleagues. They

attributed this behaviour to the manner in which science was introduced to those teachers during their pre-service training. The case study teachers accused science lecturers in tertiary institutions of being guilty of intimidating students with difficult examinations. This attitude, when imitated in secondary schools, did not help to foster positive attitudes among students towards science.

Another problem to do with the pre-service training was identified as the failure of the programme to familiarise trainees with the aim and objectives for science teaching. According to one of the teacher educators:

The pre-service training programme hardly makes any reference of the goal and objectives for the junior secondary school science to the trainees. The goal the trainees are made aware of is that of providing a foundation for the G.C.E. 'O' level work in science.

Another teacher educator described the undergraduate pre-service teacher curriculum as being overloaded with too many unimportant courses - to the extent that he believed most trainees go through the programme with little understanding of what really they were being prepared for. For the same reason, he believed the undergraduate course in philosophy of science did not enable the trainees to grasp a fair understanding of the nature of science during their pre-service programme.

The other cause of students' negative attitudes towards science was what the teachers identified as the students' unfounded bias against the subject. One teacher reported that some students, even long before they commenced the study of general science in Form 1, were convinced that science is a difficult subject. He reported that students got information from their senior mates who impressed upon them that, to be a good scientist, required a strong background in mathematics. Since mathematics is equally ill-conceived as a difficult subject by most students, a large number of students form their opinions about science even before they sit in their first General Science lessons.

The third factor responsible for students' negative attitudes towards science was what the teachers described as the disparity between

societal values and those propagated through school science. They reported that some school ideas do not conform with societal belief patterns. Citing an agricultural experience, one of the teachers elaborated: *"Planting potatoes, for example, with spacing, which is what school science teaches will lead to bigger tubers. But for a lay person, it is quantity not quality that is important"*.

With this sort of conflict, students find it difficult to extend knowledge of school science to their everyday life practices. These differences in outlook between school science values and societal expectations, the teachers believed, would downgrade science in the students' eyes.

6.6 SUMMARY

The generally proclaimed shortage of qualified science teachers at the junior secondary school level in Africa (Cole, 1970; Urevbu, 1984) was not evident from this investigation. Results of the study showed that about 73 percent of General Science teachers were trained and qualified. It is important to note that this particular finding is limited by the size of the sample (5 percent of the total number of secondary schools in Sierra Leone).

However, despite the high incidence of trained and qualified General Science teachers, over 90 percent of the qualified General Science teachers were trained to teach either Biology or Agriculture only. Only one out of every twelve qualified General Science teacher had Chemistry or Physics background, and the science teachers believed this to be one of the main reasons for the low number of students studying either Chemistry or Physics at the senior secondary level.

The results showed further that science teachers in Sierra Leone lack understanding of more recent views on the nature of science and ways of acquiring scientific knowledge. Teacher educators in science attributed this deficiency to the work load in the pre-service training programme. The researcher considered the teacher educators' explanation as confirmation of claims that science education lacks a sense of direction and philosophy to guide its curriculum and instruction (Cornelly, 1974; Harms and Yager, 1981). In addition, the

science teachers tended to conceive of scientific knowledge as an absolute entity to be packed into students' empty heads. Similar opinion was expressed by Duschl (1988) who reported that science teachers' attitudes and classroom behaviours demonstrated a view in which scientific knowledge was seen as absolute truth. The researcher's findings suggested that their understanding of the nature of scientific knowledge from a Baconian stance predisposed them to employ a 'chalk-and-talk' approach to teaching science.

The teachers recognized the present curriculum as inappropriate since it did not provide knowledge and experience that were consonant with students' needs. The General Science curriculum, from the science teachers' perspective, tended to promote aims and objectives which were unattainable for the majority of students: the content of the general science syllabuses in the research schools covered topics which the teachers believed had little or no relevance for the students or their communities.

The above findings suggest that any meaningful science curriculum innovation programme in Sierra Leone should not just be concerned with changing of content or teaching methods alone, as has often been the case in the past. There is a fundamental problem of re-educating science teachers, so that they are versed in the new philosophy of teaching science for better learning, which will lead to the development of desirable competencies and attributes among Sierra Leonean students. The next chapter reports on a trial of this kind of re-education process. It entailed an in-service programme comprising the development and trialling of new curriculum material that was intended to make junior secondary school science more meaningful to the majority of Sierra Leonean students.

**CHAPTER 7: RESULTS: ACTION RESEARCH FOR DEVELOPMENT AND
TRIALLING OF THE TEACHING PACKAGES**

This chapter presents the results of the action research that addressed Research Questions 3 and 4 which had to do with the development and trialling of two teaching packages based on the Science for All curriculum, specifically Measurement and Force.

Research Questions 3 and 4:

- RQ3. What would be the effect of an action research experience with a Science for All curriculum on the professional development of junior secondary school science teachers in Sierra Leone?
- RQ4. What would be the effect of this same curriculum on attitudes towards science of the students of these Sierra Leonean teachers?

The reader is reminded that at the beginning of the action research programme, note was taken of the attitudes towards science of students in the case study schools (see 4.5.1, p.68) as distinct from the attitudes identified in the large sample survey. The attitudes of these students at this stage constituted a kind of pre-test. At the end of the action research the science attitudes questionnaire was re-administered as one way of seeing if there had been any pattern of change in the way the students regarded science.

Similarly, the results reported in Chapter 6 on science teachers' perceptions of the junior secondary school science curriculum constituted a kind of 'pre-test'. As the action research proceeded throughout the second phase, interviews and observational work attempted to identify any changes in these teachers' beliefs on issues relating to that curriculum.

7.1 DEVELOPMENT OF TEACHING PACKAGES

The development of teaching packages which ran from August to December 1989 (see FIGURE 4.4) consisted of two phases: the draft development of the teaching packages, and the subsequent modification of the initial packages during the trial phase. The first drafts of the teaching packages were the instructional guides on measurement and force which were developed during a two-week inservice training programme. During these sessions, a series of working papers (see 4.5.3 p.78) were presented by the researcher with the aim of familiarising the participating teachers with the ideas underpinning the new Science for All curriculum. Following the framework of the proposed junior secondary school science curriculum model (see FIGURE 3.1 p.41), the teaching packages on Measurement and Force were developed collaboratively by the researcher and the participating teachers. This involved deliberation on the following curriculum areas:

1. Decision on topics: their content and context.
2. Information about students' prior ideas on the topics.
3. Perspective on the learning process.
4. The teacher's practical knowledge of the learning situation.

7.1.1 Decision on Topics: Content and Context

[a] Topic-Content

As stated in the Methodology Chapter (see 4.5, p...), the decision on content for the new curriculum was undertaken by the participating teachers. The content of the new curriculum from which the two topics (Measurement and Force) were selected for trialling is contained in APPENDIX 3.1.

[b] Topic-Context

The context for teaching and learning in the new curriculum was intended to be the real life experiences of the Sierra Leonean students. To help the participating teachers fully understand what was meant by this, the researcher guided these teachers to elicit the everyday understanding, uses and importance of the concepts of

Measurement and Force in the lives of Sierra Leoneans. The key points which delineated the context for each of the teaching packages are discussed below.

* Measurement

The goal of teaching a unit on Measurement was to enable the students to apply their understanding of international standards of measurement to interrelate and make the local units of measures more accurate for everyday use. This aim arose from deficiencies in the traditional system of measurement as described in the following sections.

Human beings apply measurement to non-spatial attributes such as time, weight and temperature in order to bring meaning to their sensory experience. Sierra Leonean people measure various quantities using culturally relevant units. For example, cloth is measured in arm-span, sticks are measured in hand-span and distances between villages in farm-lengths. Although measurements of volume, length and time are well defined among Sierra Leoneans, they do not have a measure for other attributes such as weight, speed, temperature and area that are measured in Western countries. A more detailed account of the quantities that are commonly measured in Sierra Leone is given below.

Volume

Of the three commonly used measures of volume, length and time, volume measures are by far the most widely coordinated and interrelated because of economic reasons. Since there is no measure for weight, measurement of volume is used in situations where the amount of a given material is important. Food items and other cash crops (coffee, cocoa, ginger) are bought or sold in measures of volume. Rice, which is the staple food, is measured in a wide variety of ways, from sizes of rice farms to quantity required for a family meal. One farm unit is a measure of a plot necessary to grow the amount of rice that will feed a family for a year. In commercial language, the largest measure of volume for solid objects is the 'bag' which is equivalent to the superficial volume of 100 kilograms of clean rice. The smallest measure of rice is the 'butter cup' which is the 400ml empty margarine tin. Between the 'butter cup' and the 'bag' are other sub-measures like the 'penny pan', the 'thropence pan', the 'kerosine tin' and the

'bushell' with established linear relationships between these sub-measures. For example, it is accepted that 10 'thropence pans' make one 'kerosine can', two kerosine cans' make one 'bushell', and three 'bushells' make one 'bag'. There are smaller measures of volume, depending of course on the material that is to be measured.

Length

Like volume, length has various traditional measures. One of the most common everyday objects measured for length is cloth. The village people weave cloth in long strips about 4 inches wide, these strips being sewn together to make blankets, gowns and shirts. The strips of cloth are sold by weavers using the measure of arm-span - the measure from one end of one outstretched arm to the end of the other. Other things measured by arm-span are ropes, long sticks and bridges. Measuring the height of people, however, is frowned upon because of the traditional belief that one does not measure the height of a living person. Two commonly used smaller measures of length are the hand-span (the distance between the stretched thumb and the middle finger of a stretched hand), and the foot-span. Length measures for long distances are vague. Such distances may be measured in terms of farm sizes, the number of villages between points and, at times, how long it takes to travel between points (e.g., it is one day's walk).

Time

Measures of time consist of four basic terms: day, week, month and year. The day is from sunrise to sunset, the week is the number of days between important days such as the market day or the days for prayers (Friday for Moslems, and Sunday for Christians). Months are counted as they appear in the sky, but there is no evidence of keeping track of the number of months in the year. Major farming and social activities like time for brushing new rice farms, ploughing, initiating the young into secret societies, and fishing are pegged to certain months of the year. The year is one cycle of growing rice. It begins with brushing the bush for farming in January, and ends when the last crop is harvested between November and December. There is no term to measure, or even indicate, short periods of time. On the other hand, long periods are measured relatively, most times being pegged to important events like war, famine, earthquakes etc. For

example, Joe's age could be inferred from the statement *"Joe was born a year after his uncle returned from World War II"*.

Despite their extensive applications, the local units of measures (especially for length and time) are not part of an interrelated system but are specific to the objects being measured. For this reason, weeks and months, or months and years, are not interrelated. Similarly, the various measures of length are used only when they are needed and not incorporated in a standardized system. Because of these scenarios, many educated Sierra Leoneans sit comfortably with compartmentalising their knowledge of international units of measurement, quite apart from the local units they use everyday.

To illustrate this point, during elicitation of ideas on measurement the participating teachers were asked by the researcher to estimate the weight of a 'butter cup' full of rice. None could give the answer straight off, even though a 'butter cup' of rice is the most commonly used and measured item in all Sierra Leonean homes. Because there is no measure of weight in the traditional culture, teaching or learning about international measures of weights in school has not helped to alleviate the handicaps with the traditional system for measuring weight. Nor has knowledge of international systems of measures helped to standardize local measures of length. For example, even though the 'arm-span' of an average grown up person is about two metres, in the absence of standard instruments not many educated Sierra Leoneans can easily come to grips with applying that knowledge to calibrate ropes for measuring long distances. In the same vein, secondary school students play games involving estimation of distances from reference points. They estimate the distance using foot-spans, but make no effort to convert the foot-span measures into the standardised units of measurements they are taught at school. Against this background, the aim of teaching measurement was to provide experiences that would:

1. help students to conceive knowledge of measurement as an extension of human senses;
2. familiarise students with various units of measures for length, mass, volume and time;

3. familiarise student with the metric system of measurement for length, mass, volume and time;
4. help students learn how to make measurements of length, mass, volume and time using different standard instruments;
5. help students learn how to make or calibrate local instruments for measuring length, mass, volume and time; and
6. enable students to change from one sub-unit into another on the metric system.

* Force

The building block of physics are the physical quantities in terms of which the laws of physics are expressed. The concept of force is one of these blocks. For example, the principles of work, energy and power are all derivatives of the concept of force. There are numerous examples of everyday application of knowledge about force among Sierra Leonean people. These include the use of pulleys to draw water from wells or raise objects to a height. The people also apply an understanding of the concept of force in action in building houses and bridges, as well as in carrying loads. They set traps applying knowledge of force due to an object's position, usually its height. Slings, which are used to scare birds from rice farms, also utilize the principle of force.

In spite of these diverse applications, there is no Sierra Leonean cultural term that measures or explicitly defines force. The meaning of the concept is imbedded in descriptive words such as push, pull, rub and swing, which are considered as absolute phenomena in and of themselves. To many Sierra Leoneans, a description like pushing or pulling a cart does not mean the presence of an intrinsic phenomenon such as force. Against this background, the literal meaning of force for people is compulsion - to force someone or something. This automatically constitutes a framework that is contrary to the natural language of Physics which uses force as a noun, not as a verb. Therefore, the main aim of teaching a unit on Force was to provide experiences that would help students:

1. develop an understanding of the scientific meaning of the term force;
2. identify and qualitatively describe kinds of forces in everyday activities; and
3. be familiar with some of the effects of common types of force.

7.1.2 Information About Students' Prior Ideas

The view of student learning as conceptual change which was adopted for teacher inservice work in the present study necessitated knowledge of students' prior ideas on measurement and force to guide the development of teaching packages. Even though there were no research findings on Sierra Leonean students' ideas on these topics, the traditional cultural scenarios described above were sufficient to suggest what could be expected from these students. Consequently, teaching packages were developed on the assumption that students were well-versed in knowledge of local measures of volume, time and length, but had no measures for weight and force. Furthermore, assuming Form I students to be reasonably familiar with international units of measurement, it was possible that these units were not coordinated with the local units and thus not utilised in the students' everyday activities. Similarly, it was assumed that the students' understandings of the concept of force were those dictated by the everyday use of the word.

7.1.3 Perspective on the Teaching and Learning Process

The perspective on the learning process adopted in planning the teaching packages was grounded in the constructivist tradition which views learning as coming about through the active construction of meaning by the learner. This suggested a teaching strategy having four stages: (1) exploration of students' ideas; (2) development of the concept; (3) application; and (4) evaluation.

The exploration stage comprised two phases, (a) focusing and (b) elicitation. The focusing phase was designed to give students the

opportunity to develop a sense of purpose and motivation for learning the topic. The elicitation phase was intended to encourage the students to make their ideas on the topics explicit and bring these ideas to conscious awareness by making them public. The developmental stage constituted the bulk of the instructional scheme, and it consisted of two phases: clarification and formalization of students ideas. During clarification, the students' ideas as elicited from the preceding stage were sharpened by making the students conscious of appropriate alternative ideas. The new ideas were then formalized into a language and principle of science appropriate to the level of the students.

During the application stage, students were given the opportunity to apply the newly developed ideas in a variety of ways including practical exercises as well as addressing community related problems. The purpose here was to consolidate and reinforce the learned concept. The final stage of the teaching scheme was evaluation of students' understanding of the learned concept. The test used here assessed both attitudinal and conceptual change.

7.1.4 Teachers' Practical Knowledge of the Learning Situation

The other guiding principle for the teaching packages was the teachers' practical knowledge of the learning situations. Problems of large class sizes, insufficient teaching aids, and lack of laboratory facilities for the junior classes, were some of the constraints that were taken into account for planning the teaching/learning activities.

7.1.5 Instructional Guides

Based on the four curriculum inputs discussed above, instructional guides for both topics were prepared as shown in FIGURES 7.1 and 7.2.

M E A S U R E M E N T

Stage	What?	Why?	How?
1.	EXPLORATION	To establish sense of purpose for studying measurement and delineate units of measures that are familiar to students.	Through brainstorming
	(i) Focusing	To enable students to appreciate the importance of their experience of measurement as everyday working knowledge.	Guide the students to: - Realize the relativeness of descriptions such as 'tall', 'big', 'short' and 'old'. - Develop an understanding that units of measures are extensions of human senses since they add meaning to questions such as how tall or how big.
	(ii) Elicitation of students' prior ideas.	To help students focus on their prior ideas about the different systems of measures with which they are familiar and make these ideas public.	Present students with tasks that test their application of knowledge of measures in describing specific activities e.g., - Writing essays describing how to cook rice to somebody who has never cooked rice before. - Asking direct questions that probe students' familiarity with units of measures for length, mass, volume and time.
2.	DEVELOPMENT OF THE CONCEPT	To clarify and modify students' ideas on measurement.	
	(i) Clarification	To help students classify units of measurement (local and international) for length, mass, volume and time.	From the elicitation examples; - Guide students to identify which of the units are used for measuring length, mass, volume and time. - Help students to distinguish between local and international units of measurements.
	(ii) Formalization	- To acquaint students with the two international units of measurement the metric and foot poundal system (F.P.S.) of measurement for length, mass, volume and time. - To help students acquire skills for making measurements.	Guide students to tabulate the main units of the metric and the F.P.S. systems of measurement for length, mass, volume and time: - Teach students about the sub-units of the metric system of measurement for length, mass, volume and time. - Help students acquire simple techniques for changing from one subunit of the metric system to another (eg., centimeter to kilometer). Provide practical experiences such as teaching students how to measure: - Weight of objects using simple balances, - Volume of liquids or solids using measuring cylinders, - Distances using tape rules, meter rules, foot rules etc.
3.	APPLICATION	To consolidate and reinforce the newly acquired knowledge and skills on measurement.	Engage students in activities that require application of the newly learned concept in real life situations.
	(i) To enable students to use the new ideas with confidence.		Encourage students to apply knowledge of international standard measures to Standardize some of the local units of measurement (eg. measuring the volume of one 'butter cup' of rice in litres and measuring the weight of one 'butter cup' of rice in pounds or kilogrammes).

		b) Calibrate local measuring instruments using standard measures, e.g., (i) Calibration of palm wine selling bamboo cups in litres. (ii) Calibration of calabashes for measuring the volume of oil for cooking or making soap. (iii) Calibration of ropes for measuring distance. c) Prepare students to be able to record unfamiliar events by teaching them, (i) How to make estimates of distances in standard units by using foot spacing, arm-spans etc. (ii) How to estimate the time from the position of the sun and the length of their shadows.
	(i) To help students acquire proper communication skills.	Engage students in communication exercises that require precision e.g., drawing directory maps or writing descriptive essays on topics such as how to make local soap.
4.	EVALUATION	To test students' understanding (both affective and cognitive) of the unit on measurement. Through classroom questioning, assignment, group project and formal tests, check whether students can: a) Distinguish between local and international units of measurement, and between the metric and the F.P.S. system of units, b) Change from one sub-unit of the metric system into another, c) Accurately measure distances, volume and time using standard measuring instruments, d) Give precise descriptions of processes such as baking cake, making local soap.

FIGURE 7.1 : Instructional Guide for the Teaching Package on Measurement

F O R C E

Stage	What ?	Why ?	How ?
1.	EXPLORATION	To establish sense of purpose for studying Force and solicit students' prior ideas on this concept.	Brainstorming
	(i) Focusing	To arouse students' interest in studying a topic on Force.	Use everyday examples to emphasise the importance of knowledge of Force, e.g., ask for students' explanations to the following phenomena: (i) Why is it difficult to walk on highly polished floors? (ii) Why do objects fall when they are released from a height above the ground? (iii) Why do vehicles slow down when negotiating curves?
	(ii) Elicitation of students' prior ideas.	To encourage students to reflect on their prior frameworks on the concept and make these frameworks public.	a) Use students' explanations for the above phenomena to capture the key word - FORCE. b) Solicit students' understanding of the term Force, and examples of types of forces with which they are familiar.
2.	DEVELOPMENT OF THE CONCEPT	To clarify and modify students' conceptions on Force.	Present students with the scientific conception of Force.
	(i) Clarification	To clarify students' (or misconceptions) about	Present students with selected frameworks of forces in action, (i) Reactional forces on objects at rest. (ii) Tensional forces in pulling objects. (iii) Frictional forces in opposing motion. (iv) Magnetic force in producing motion. Encourage students to describe how these frameworks agree or disagree with their prior conceptions:
	(ii) Formalization of students' ideas.	To acquaint students with the scientific meaning of Force, some examples of kinds of forces, and a qualitative account of the uses and effects of some of these forces.	a) Use the above examples to teach students the scientific framework of Force. b) Rectify students' classification of examples of kinds of forces, and help them explain in their own words the meaning of some of these forces (e.g., gravitational, frictional and reactional). c) Organize activities to demonstrate the effects of common types of forces (eg, gravity, magnetic and frictional). d) Provide students with qualitative explanations of the uses and effects of some common types of forces (e.g., frictional forces enables us to walk, but they can also cause wear and tear on objects. Centripetal forces keep objects moving in a circle, but are dangerous when a fast moving object moving in a straight line approaches a curve).

3.	APPLICATION	To consolidate and reinforce the newly learned concept.	Engage students in small projects such as identifying kinds of forces in play in their communities. a) For example naming the kinds of forces involved: (i) A hanging hammock. (ii) Drawing water from a well. (iii) Tug of war and walking. b) Encourage students to identify areas in which the principle of force are applied in their communities.
4.	EVALUATION	To test students' understanding of the unit on Force.	Through classroom questioning, assignments, small projects and formal tests. Check whether students (i) Understand the scientific conception of Force. (ii) Can identify and describe examples of kinds of forces common in their localities. (iii) Can offer qualitative scientific explanations for common phenomena applying principles of force.

FIGURE 7.2 : Instructional Guide for the Teaching Package on Force

7.2 TRIALLING THE TEACHING PACKAGES

Trialling of the teaching packages on Measurement and Force constituted the second phase of the action research programme. It consisted of a cyclic process of trialling - evaluating - modifying - retrialling.

Using the instructional guides described in FIGURES 7.1 and 7.2 as a basis, weekly lesson plans were developed by individual case study teachers on the units they were teaching. The lesson plans were coordinated by the researcher to ensure that the same content was being taught in all three research schools. One sample of a teachers' lesson plan may be seen in FIGURE 7.3. The remaining lesson plans for the entire units on Measurement and Force are contained in APPENDICES 7.1 and 7.2.

SUBJECT: GENERAL SCIENCE

DURATION: 40 Minutes

TOPIC: CONVERSION from one unit to the other.
AIM: To show that a particular distance for weight of an object is the same only units of measurement make their figures vary in magnitude.
OBJECTIVE: By the end of the lesson children should from the outlined exercises and the teacher's explanations, be able to
(1) convert from centimetres to metres,
(2) convert from metres to kilometres
(3) multiply or divide where such are necessary.
MATERIALS: Exercises on conversion, table to guide children and worked examples.
INTRODUCTION: Teacher repeats the history of how the metric system came about. The metre as the basis and foundation unit from which like cm, mn, km, dm were derived. The table is summarized on the B/B and children asked to read.
10mm = 1cm, 10 cm = 1dm, 100cm = 1m
1000m = 1km.
DEVELOPMENT: Exercises are given to children after teacher has done two or three examples on the board for all to see.

Teacher goes around the class and marks the children's work. This enables teacher to note the number of students who are following the lesson. If more lag behind, exercises are done on the board by volunteers or appointees. These do the work and explain alongside

for the whole class. Two of such exercises may be enough.

Exercises given are this time meant to be done correctly. Teacher and children do the corrections together on the board.

CONCLUSION: *The lesson is concluded. The teacher formulates the rules : when we convert from a larger unit to a smaller one - we multiply, but when we convert from a smaller unit to a larger one we divide.*

In a given problem children should identify the direction of conversion and apply appropriate rules and table.

ASSESSMENT: *Teacher asks a few questions - 'Hot mental' to see what children have gathered at all from the lesson.*

FIGURE 7.3: Sample of Trial Lesson Plan

The trialling exercise was monitored by the researcher through classroom observations and interviewing (see FIGURE 4.4 p.63). Depending upon evaluations made mutually by the researcher and the particular case study teacher, some of the lesson plans were modified for retrialling. As pointed out in the Methodology Chapter, different streams of Forms 1 and 2 classes at the St. Andrews and Bo schools were used for trialling and retrialling purposes. At the third research school at Gerihun, where there was only one stream each for Forms 1 and 2 classes, only trialling lessons were conducted. Results of the trial and retrial exercises from the three research schools are discussed in the following sections.

7.2.1 Trial Results for the Teaching Package on Measurement

The package on Measurement was taught during six sessions consisting of 8 forty minute periods in each trial or retrial class. A summary of the aims and objectives of the six lessons is shown in FIGURE 7.4.

Lesson	Duration (minutes)	Main Aim	Specific Objectives
1	80	To establish the importance of measurement in science and elicit systems of measurements familiar to the students.	To help students put across their understanding about - why apply standards of measures to attributes, - examples of quantities normally measured, and - some of the instruments and units of measurement
2	40	To clarify students ideas on units of measurement and teach them about the metric and British units of measurement.	To help students - develop an understanding about the importance of standardization of measurement in science, - learn about the main units of measurement for length, mass, volume and time in both the metric and British system, and - learn about the various subunits of measurement for length, mass, volume and time in the metric system.
3,4	40 each	To teach students how to make accurate measurements.	To help students - Identify names of common measuring instruments, - Learn to make accurate measurements of distance, weight, volume and time using some of these instruments, and - Use the correct unit in expressing measurable quantities
5	40	To teach students how to convert from one unit into another on the metric scale.	To help students - Learn a rule of thumb for changing from one unit into another, - Solve simple mathematical problems on conversion.
6	80	To teach students how to make models of simple measuring instruments.	To help students To calibrate/make simple instruments for measuring distance, weight, volume and time.

FIGURE 7.4: Summary of the Aims and Objectives of the Six Lessons on Measurement

Lesson 1

The aim of this lesson was to elicit systems of measurements that were familiar to the students, and to establish a sense of purpose for studying measurement in science. Both the two case study teachers and the researcher had difficulties in achieving this aim. The researcher found it virtually impossible to elicit information from the students in the third research school at Gerihun. In the other research schools, the inexperience of these teachers in utilizing student ideas to guide the lessons towards a theme meant that their students did not recognize local units of measures as examples of standards of measurement, or establish the importance of studying measurement in science.

To illustrate this problem, proceedings of the first twenty minutes of the trial lesson at Bo school is reproduced below:

Teacher: Who can tell us something about the topic on
the board?

Pupils: (No response)

Teacher: When do we measure?

Pupils: (No response)

Teacher: What are some of the things we normally measure?

Pupils: Distance, weight, temperature, time, angles.

Teacher: In what units do we measure weight?

Pupils: Pounds, stones, ounces

Teacher: In what units do we measure distance:

Pupils: Yards, miles, inches, feet

Teacher: In what units do we measure volume?

Pupils: (No response)

The students demonstrated no knowledge of units of measurement for volume, possibly because the volume of things they use in everyday life is being measured using local units. The teacher at that point did not know how to proceed with the brainstorming exercise to elicit from the students examples of such units. Instead, he broke off a good dialogue that was beginning to develop between himself and the class, and engaged the students in measuring activities as described in APPENDIX 7.1. At the end of the lesson, the teacher told the researcher:

I just did not know how to continue with the questioning. Fortunately, I had other activities planned, so I asked the pupils to continue with that.

Similar problems were encountered by the case study teacher at the St. Andrews school. Because of these difficulties, the lesson was remodified for retrial.

The retrial was undertaken by the researcher to demonstrate to the case study teachers at both the St. Andrews and Bo schools the technique of eliciting and using students' ideas to generate further questions or learning activities. At Gerihun where the researcher was actually trialling the package on Measurement, the only other case study teacher in that school teaching the unit on Force observed many of the researchers' lessons. Details of the retrial lesson in the two schools are given below.

During the retrial lessons, the researcher confronted students with brain storming questions and activities as detailed below. At Bo school, the researcher wrote the sentence *"She is a tall lady"* on the board and asked the students to write down in their notebooks what they believed would be the height of that lady. After allowing about two minutes, the researcher went around the class and selected four answers at random and wrote those on the board. Different estimates by the four students gave rise to constructive arguments among the students. One student argued *"She cannot be 6.0 feet. Women are not that tall"*. The researcher allowed the argument to go on for five minutes before posing the next question: *"How can we resolve this matter about the lady's height?"* Some of the students replied by stating that *"We have to measure her height"*. The researcher next asked: *"Why do we have to measure her height?"* Many answers were given but one particular student said: *"Because we want to know her correct height."* The researcher wrote the answer on the board underlining the word correct. He then asked the next question: *"Why do we measure things?"* This was followed by subsequent questions like: *"What are the things we normally measure? What instruments do we use for measuring these quantities? In what units are these quantities measured?"*

To highlight examples of local units of measure, the researcher asked the question *"Are these the instruments or units people use in the market or villages to measure these quantities?"* Subsequent questions such as *"What are the units used by traders for measuring volume? How*

do people measure distances in your village? were able to delineate examples of local units of measurements from the students. A similar approach was employed in the demonstration retrieval lesson at St. Andrews school.

On each occasion, the researcher summarized the lesson by guiding the students to complete the following Chart:

Quantity Measured	I n t e r n a t i o n a l U n i t s	Local Units
Distance	Centimeters, miles, yards, feet, inches	Farm length, hand-spans, foot span
Weight	Pounds, stones, ounces	Hand estimate
Volume		Butter cup, thropence pan, kerosine can, drum, hand
Time	Seconds, minutes, hours, days, weeks, years	Days, week, months, years. Length of shadows

FIGURE 7.5: Examples of Units of Measurement Elicited from the Students.

The Chart showed that students displayed more familiarity with the British units of measurement, even though the metric system is the official unit of measurement in Sierra Leone. Furthermore, they displayed lack of knowledge of any of the two international units of measurement for volume.

At the end of the demonstration lesson, the case study teacher for the unit on Measurement at Bo school told the researcher:

I could feel the difference between your lesson and mine. Your lesson went on fluently. It was interesting listening to the students debate which estimate of 'tall' was more accurate than the others.

The other case study teacher in that school observed that none of the students seemed left out in the class discussion, a situation he described unusual for General Science lessons. The case study teacher for the unit on Measurement at the St. Andrews school reported after the demonstration lesson:

There was anxiety (sic, but meaning Keenness) in the faces of the students when you got to the examples on local units. Everybody wanted to contribute something.

Lesson 2

The aim of the second Lesson was to teach students about the metric and the British units of measurement. During this lesson, students were taught to distinguish between local and international units of measurements. Through classroom demonstrations such as comparing the 'arm-spans' of different sizes of students, or measuring the volume of different commercial 'butter cups', the case study teachers were able to establish with their students the non-uniformity of local units of measurements. The teachers thus emphasized the main advantage of international units of measurement as being the same all over the world.

After clarification of their examples of units of measurement as shown in FIGURE 7.5, the students in each trial class were given a chart which summarized the metric and British units of measurement for length, mass, volume and time. The metric units of measurement and the mathematical relationships between the various sub-units of that system for the quantities length, mass volume and time were also included in the summaries. All case study teachers had no difficulty with this Lesson. The original lesson plans therefore needed no modification for retrial.

Lessons 3 and 4

Lessons 3 and 4 were practical exercises which taught students how to make measurements of length, weight, volume and time. At the beginning of Lesson 3, each case study teacher divided his class into small groups of students, the number of students in a group determined by the availability of measuring instruments in the particular research school. At Gerihun where there were only a limited number of instruments, the researcher divided the class into four groups, each containing about seven students. At both the St. Andrews and Bo schools, classes were divided into smaller groups of three or four students at most.

The following is an example of the kind of activities undertaken in one of the trial classes.

Materials: *Metre rules, tape rules, scales, spring balances, weight boxes, measuring cylinders, stop watches, and other objects.*

Instructions:

- Step 1: *Measurement of distance.*
 (i) *Measure the length of your desk.*
 (ii) *Measure the length of your exercise book.*
 (iii) *Measure the height of the wall in your classroom.*
- Step 2: *Measurement of weight.*
 Weigh the following objects.
 (i) *The mathematical set.*
 (ii) *The wooden block.*
 (iii) *The stone.*
- Step 3: *Measurement of time.*
 (i) *How long does it take a pupil to walk to the school gate and be back?*
 (ii) *How long does it take the pupil to round the building twice?*
- Step 4: *Measurement of volume.*
 Use the measuring cylinder to measure:
 (i) *the volume of a given amount of water,*
 (ii) *the volume of the objects provided (stone, sand, etc).*

In each class, the instruments provided were rotated among groups thus ensuring that every student made measurements of length, weight, volume and time during the course of the two lessons. During the

group activities, the teacher went around ensuring that every student participated in the activities. At the end of Lesson 4 each case study teacher summarized the activities of the two lessons by asking individual groups to present their results. Each group was asked to name the instruments they had used and provide the results of their measurements. Those results were written in tabular form, comparing the results for measurement of the same item by different groups. A sample of the tables is shown in FIGURE 7.6.

Quantity Measured	Object Measured	Instrument Used	Result
Distance	Length of desk	Metre rule	60cm/59.6cm
	Length of exercise book.	Metre rule	20cm/23cm
	Height of classroom	Tape rule/metre rule.	281cm/2.80m
Weight	The mathematical set	Spring balance/scale	250/gf/370gf
	The wooden block		45gf/80gf/
	The stone	Scale	110gf/200gf
Time	Time taken to walk to the school gate and back.	Stop watch/ electronic watch	3 minutes/ 120 seconds
	Time taken to run round the building twice.	Stop watch/ electronic watch	20S/19S/22S
Volume	Volume of water	Measuring cylinder	350ml/200ml
	Volume of stone	Measuring cylinder	5ml/40ml
	Volume of sand	Measuring cylinder	45ml/63ml

FIGURE 7.6 : Results of the Measuring Exercises in Lessons 3 and 4 on Measurement

In discussing these results, the case study teachers also emphasized the correct use of units. It was a common experience across all three schools for students to associate the wrong units with the quantities being measured. These included pronouncements like "*The volume of the water is 250 centimeters*" (meaning to say 250 millilitres), or "*The weight of the stone is 150 pounds*" (meaning to say 150 grammes). Under those circumstances, the teachers rectified the individual student or group errors by working through them with the whole class.

During the first trial of Lesson 3, the case study teachers at the St. Andrews and Bo schools restricted activities to their respective classrooms. For the retrial, the lesson plan was remodified to include out-of-classroom activities such as: (i) measuring the dimensions of the football field, (ii) recording how often people enter the principal's office, and (iii) measuring the volume of the bucket used for collecting water from the school water well. Both teachers expressed satisfaction with their retrial lessons. After the retrial, the teacher at the St. Andrews school told the researcher:

It was a good lesson. The digression made the class less formal. Even some of my fellow teachers were surprised to learn that we were doing science out there in the field.

The other teacher at Bo school reported as follows:

The students liked the innovation. They are always looking out for activities. It is good for them because I know activity learning helps students to remember more.

Lesson 5

In Lesson 5 students were taught how to convert from one sub-unit into another on the metric system of measurement for length, mass, volume and time. The aim was to help the students acquire operational skills for changing say centimeters to kilometers or vice versa. To develop the lesson, each case study teacher revised with his students the mathematical tables on the metric units of measurement which were

summarised as notes at the end of Lesson 2. This was followed by the teacher writing a simple conversion problem on the board and solving it with the class. Examples of such problems were:

- (i) *Change 0.5 kilogram to milligrams.*
- (ii) *The distance from the school gate to the principal's office is 250 meters. How far is this in kilometers?*
- (iii) *How many millilitres of water can fill a 2.5 litre container?*

After solving two or three examples on the board, the teacher wrote some exercises on the board to be solved by the students in their exercise books. During the individual working session, the teacher went around correcting the students' work. Volunteers were eventually called upon to solve the problems on the board, explaining the steps taken to the rest of the class.

Results of the first trials of this Lesson in the three research schools revealed that students had difficulty working with decimal numbers. In one of the teachers' worked examples (*Change 8 millimeters to kilometers*), the students proved incapable of handling the number of zeros involved in the calculation, viz.,

$$\begin{aligned} 8\text{mm} &= \frac{8}{10} \text{ cm} \\ &= 0.8 \text{ cm} \\ \\ &\frac{0.8}{100} \text{ m} \\ &= 0.008 \text{ m} \\ \\ &\frac{0.008}{1000} \text{ km} \\ &= 0.000008 \text{ km} \end{aligned}$$

After his trial of this lesson, the teacher at Bo school made the following observations in his notebook.

- (i) *the pupils could not work comfortably with decimal points.*
- (ii) *They can only do the work on conversion when there is a table or hint accompanying the problem.*
- (iii) *Pupils sometimes cannot choose correct operations - multiplication or division to convert from one unit to another*

Indeed, the number of zeros in the above example could prove difficult to handle even for more senior students. The teachers' selection of

problem was clearly a reflection of preoccupation with textbook-type examples and of less concern with the relevance aspect regarding everyday life. For the retrial lessons, it was agreed that the teachers should minimize the mathematical operation and instead help the students acquire a rule of thumb for conversion. The rule of thumb formulated was

When we change from a higher subunit to a lower subunit we multiply (H-L-M) and when we change from a lower subunit to a higher subunit we divide (L-H-D).

This technique produced more satisfactory results than the first trial. Both case study teachers reported that even students who had difficulty with the mathematics could at least describe correctly the processes to follow in changing from one sub-unit into another.

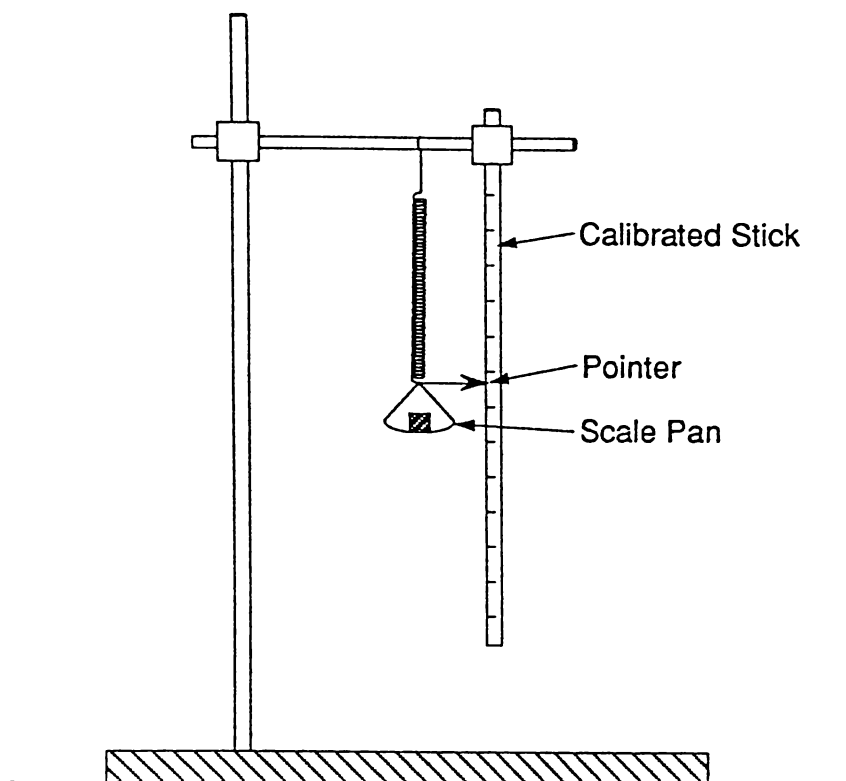
Lesson 6

During the final lesson, students were taught how to make models of local instruments for measuring distance, weight and volume. At Bo school, the emphasis was on the calibration of spring balances for measuring weight. The instruction that was written on the board for this activity is reproduced below:

Materials: *Springs, scale pans (tin lids or flat boards), strings, pins, standard weights, clamps, stands, sticks and objects to be weighed.*

Instructions:

Step 1: *With the materials provided, set up the apparatus as shown in the diagram below:*



Step 2: When the scale pan is empty, mark the position of the pointer on the calibrating stick as zero.

Step 3: Add 20g weight at a time to the scale pan, and each time mark the position of the pointer on the stick. Keep adding until the total weight in the scale pan is 200g.

Step 4: Remove all the weights from the scale pan. Check if the pointer returns to the zero mark when the scale pan is empty.

Step 5: Use the calibration on the stick to measure the weights of the objects provided (stones, rubber corks and small wooden blocks).

The researcher observed that the students needed guidance to set up the apparatus. Apart from that, they completed the rest of the exercise with minimum assistance from the teacher. Asked what he felt about the lesson, the teacher replied:

It was interesting, I am sure the exercise will help the students to understand better the principle of weighing things.

Students at the third research school at Gerihun were taught how to calibrate sticks and ropes for measuring distance. To calibrate ropes

for measuring long distances, students used a 50 meter tape rule to knot ropes at specified intervals. For the first 5 meters, the ropes were measured and knotted at 1 metre intervals, and the remaining lengths at 5 metre intervals. For measuring shorter distances, straight edged sticks and bamboo canes were placed against standard meter rules and distances were marked at 0.5 centimeter intervals. The remaining of the lesson engaged the students in measurement activities (e.g., their heights, the length of the football field, the dimensions of their classroom) using their constructed models.

The teacher at St. Andrews school focussed more on teaching students how to equate some of the local units of measures to standard units. The following is a reproduction of part of the instructions that were written on the board for that particular lesson:

Materials: Butter cups, measuring cylinders, scales, meter rules, tape rules, standard weight, rice and empty bottles used for selling palm oil.

Instructions: Use the instruments provided to do the following exercises:

- (a) Measure:*
 - (i) the volume in litres of one 'butter cup' full of rice.*
 - (ii) The weight of one 'butter cup' full of rice.*
 - (iii) The volume of water in litres that will fill one pint bottle.*
- (b)*
 - (i) How many walking steps can you make to cover a distance of 10m?*
 - (ii) Measure the distance between your classroom and the school gate using foot spacing.*
- (c) Measure the lengths of your 'hand-span' and 'arm-span' and use the results to estimate:*
 - (i) the length of your desk.*
 - (ii) the length of your classroom.*

According to the researcher's assessment of the lesson, the students had real fun doing the exercises. Only one exercise - that of measuring the volume of the 'butter cup' of rice - required the teacher's clarification. In that particular exercise, students just poured the measured quantity of rice into the cylinder, shook it well, and read the graduated number against the level as the equivalent volume of the rice. To rectify that problem, the teacher engaged the

class in a dialogue which went as follows:

Teacher: *What is the volume of one 'butter cup' of rice?*

Pupil 1: *360 ml*
Pupil 2: *450 ml*
Pupil 3: *400 ml*

Teacher: *Which of these answers is correct?*
Pupils: *Pause*
Teacher: *Okay, can somebody come up and measure the volume for the class to see?*

Pupils volunteered. The teacher chose one who repeated the same procedure as described above:

Teacher: *What is the volume?*
Pupil: *It is 390ml*

The teacher passed around the cylinder with the rice in it for the rest of the class to see.

Teacher: *Is he correct?*
Pupils (Chorus): *Yes*
Teacher: *Can anybody tell me how we measured the volume of sand before?*
Pupils (Chorus): *Yes*
Teacher: *How did we do it?*

One of the pupils explained the displacement method of measuring volume of insoluble substances which was covered in one of the earlier lessons.

Teacher: *I want you (the same volunteer) to measure the volume of the rice using that method (the displacement method).*

The pupil added some water into the empty cylinder and read out the volume. The teacher asked other students for confirmation and they all agreed. The teacher then wrote the initial volume of the water in the cylinder as $V_1 = 240\text{ml}$.

The pupil added the rice and the new volume, after being confirmed by other pupils, was written on the board by the teacher as $V_2 = 550\text{ml}$.

Teacher: *What is the volume of the rice?*
Pupil: $V_2 - V_1 = 550 - 240 = 310 \text{ ml}$
Teacher: *What was the volume before?*
Pupils (Chorus) *390ml*
Teacher: *Can anybody tell me why the two answers are different?*
Pupils: *No response*
Teacher: *Which of the two answers is correct?*
Pupil 1: *The second answer.*
Teacher: *Why?*
Pupil: *Silence.*
Teacher: *Okay as your assignment, I want you to go home and find out which of the two answers is correct and why.*

The researcher who had anticipated this problem because of the difficulty level of the task for that age of students, held the following discussion with the teacher at the end of the lesson:

Researcher: *Did you anticipate this problem about the volume of the rice to arise?*
Teacher: *No*
Researcher: *But you handled it well. It was quite good. Why did you stop short of telling the pupils the correct answer?*
Teacher: *I have told them before when we measured the volume of sand. I wanted them to go and find out for themselves.*
Researcher: *What did you think about the lesson?*
Teacher: *I feel good about it. I myself was actually learning some of those basic things for the first time.*

Because first trials of this lesson revealed no difficulties with any of the case study teachers, no modification was necessary to the original lesson plans for retrieval.

7.2.2 Trial Results for the Teaching Package on Force

The package on Force was taught during four sessions comprising six forty minute periods in each stream at the St. Andrews and Bo schools. The first lesson of this unit was repeated at the third research school at Gerihun for reasons that will be explained shortly. A summary of the aims and objectives of the four lessons is shown in FIGURE 7.7.

Lesson	Duration (Minutes)	Main Aim	Specific Objectives
1	40	To establish the importance of studying force, and elicit students' prior understanding of the term.	To help students put forward: i) their understanding of the term force, and ii) examples and meaning of types of forces they are familiar
2	80	To familiarize students with the scientific framework of force.	To help students get some feeling about the concept of force and be able to describe the outcome of some common types of forces on objects.
3	40	To teach students the scientific meaning of force and examples of common types of forces.	To help students i) clarify their prior conceptions about force, ii) learn about the scientific meaning of force, iii) be able to name and describe qualitatively examples of common types of forces.
4	40	To teach students the affects and effects of some common types of forces.	To help students understand qualitatively how knowledge of Force can explain some real life phenomena e.g. walking, flying and skating.

FIGURE 7.7: Summary of the Aims and Objectives for the Four Lessons on Force.

Lesson 1

The aim of the first lesson was to establish the importance of studying a unit on Force and solicit students' prior conceptions on the topic. To introduce the lesson, the teacher at St. Andrews school engaged students in the following dialogue:

Teacher: *Who can tell me why people are not allowed to drive vehicles with smooth tyres?*
Pupil: *Because the police will arrest them.*
Teacher: *Why will the police arrest them?*
Pupils: *(No response)*
Teacher: *Has any of you tried to walk on a polished floor?*
Pupils (Chorus) *Yes*
Teacher: *Is it difficult or easy?*
Pupils (Chorus) *It is difficult*
Teacher: *Why is it difficult?*
Pupil: *It is slippery?*

Teacher: *Why is it difficult to walk on a slippery surface?*
Pupils: (No response)

At that point, the teacher wrote the word Force on the board and continued the conversation as follows:

Teacher: *Who can pronounce the word on the board?*
Pupils (Chorus) *Force*
Teacher: *Have you come across that word before?*
Pupils (Chorus) *Yes*
Teacher: *What does it mean?*
Pupil 1: *Force is when you force somebody to do something.*
Pupil 2: *Force is the energy we apply to something that makes it move.*
Teacher: *Any other meanings?*
Pupils: (No response)
Teacher: *Can you give me examples of Force?*
Pupil 1: *Police force*
Pupil 2: *Military force*
Pupil 3: *U.S. Navy*
Pupil 4: *Force of gravity*

The teacher summed up the lesson by informing the students that they would continue the discussion in the next lesson to find out the scientific meaning and examples of force.

Similar approaches were employed by the teacher at Bo school and the class participation was equally encouraging. In addition, students in this school appeared quite knowledgeable in reciting textbook definitions and examples of force as illustrated below:

Teacher: *If I ask you to describe what the word force means, what will you tell me?*
Pupil 1: *Force is a push or pull*
Pupil 2: *Force is the weight of an object towards the earth*
Pupil 3: *Force is something which changes a body's state of rest.*

However, there was still a good number of these students who carried the literal understanding of the term. Examples of force for this category were similar to those identified by students at St. Andrews school. Both case study teachers in these schools were satisfied with their trial lessons. The lesson plans needed no modification for the retrialling by these teachers. It should be noted that the first

trials of Lesson 1 on Force took place after the researcher's demonstration of the retrial of Lesson 1 on Measurement at both schools.

For his first trial of this lesson, the case study teacher at Gerihun encountered similar problems that confronted the researcher during his trial of the first lesson on Measurement in that same school. This teacher, like the researcher, also failed to get the class involved in putting across their ideas as illustrated below.

Teacher: *Who can tell us what the word force means?*
Pupils: (No response)
Teacher: *Have you heard of the word before?*
Pupils (Chorus): *Yes*
Teacher: *Can you tell me in your own words what your understanding of that word is?*
Pupils: (No response)
Teacher: *Can anybody give me an example of force?*
Pupils: (No response)

Pupils in this first lesson were so unresponsive that the teacher decided to repeat the lesson. This time the case study teacher used input from the researcher, based on the latter's observation of that same lesson in the other research schools. The teacher confronted the class with ideas obtained from students in the other research schools, each time asking if the students were familiar with such ideas. Part of the retrial proceedings is reproduced below:

Teacher: *Some people describe force as a push or pull. Have you heard of that before?*
Pupils (Chorus): *Yes*
Teacher: *What do you understand by that?*
Pupil: *Because when you force something you are either dragging it or pushing it away.*
Teacher: *Are there other reasons why they describe force as push or pull?*
Pupils: (No response).
Teacher: *Who can give me examples of force?*
Pupils: (No response).
Teacher: *Have you heard about the word gravitational force before?*
Pupils (Chorus): *Yes*
Teacher: *What does it mean?*
Pupils: (No response)
Teacher: *Is police an example of force?*
Pupils (Chorus): *Yes*

Teacher: *Can you give me other examples of force?*
Pupil 1: *Military force*
Pupil 2: *Marine force*

This repeat lesson was a considerable improvement compared to the first one. The teacher that time succeeded in getting at some of the misconceptions held by these students about the concept.

Lesson 2 and 3

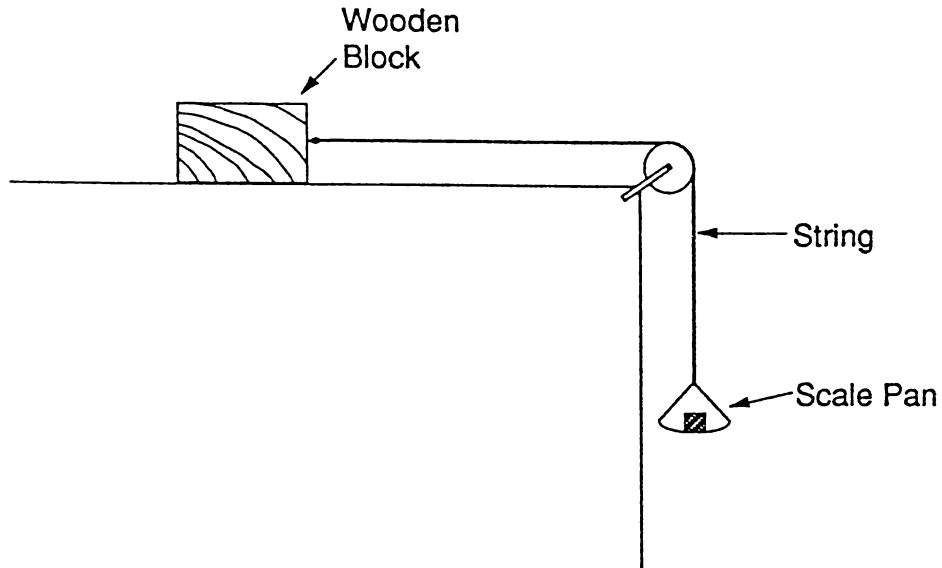
Lessons 2 and 3 were practical classes aimed at familiarising students with examples of scientific frameworks for force. To enable them to conceptualize the scientific meaning of the term, students were engaged in activities that illustrated examples of common types of forces - gravitational, reactional, tensional, magnetic and frictional. An example of the type of activities the students were engaged in is reproduced below.

Materials: *Bar magnets, nails, sizable stones, strings, clamps, wooden blocks. pulleys and scale pans.*

Instructions: *Use the materials provided to do the following exercises:*

- (a) (i) *Hold a stone in the air. Let it go. Explain what happens and why.*

 (ii) *Tie a piece of string around the stone. Hold it in the air by holding onto the end of the string. Does the stone fall down? If no, explain what stops it from falling. If yes, explain why it falls.*
- (b) *Hold a bar magnet in one hand. Slowly move it towards a nail resting on your desk. Explain what you observe and feel.*
- (c) *Set up the apparatus as shown in the diagram below.*



Add the stones provided one at a time into the scale pan. Does the scale pan or the wooden block move? Explain what is stopping the scale pan and its content from falling down? What will happen to the scale pan and its content if you cut the string midway between the scale pan and the wooden block? Explain why.

At the end of Lesson 3, the teachers utilized the results of the practical exercises to present students with scientific frameworks of force and examples of the common types of forces. An example of the frameworks that were written on the board in one of the trial classes as a summary of the two lessons is reproduced below:

1. *Force is a push or pull.*
2. *Force can cause a change of motion.*
3. *Force can stop a moving object or change its direction.*
4. *Force can start an object moving.*
5. *Force can change the shape of objects.*

Examples of force -

1. *gravitational*
2. *reactional*
3. *tensional*
4. *magnetic*
5. *frictional.*

All three teachers expressed satisfaction with the students' participation in the practical activities in Lesson 2. However, two problems emerged that were common across the three research schools. Firstly, students from the three schools displayed lack of understanding of the concept of weight for bodies in equilibrium. For example, students in all three schools knew that a stone let free in the air fell because of the "pull of gravity on the stone". But

when that same stone was suspended in the air by tying a string around it, the students' understanding of 'pull of gravity' became obscured. In that new frame, they could not tell what had happened to the pull of gravity because the stone no longer fell.

The following conversation between the case study teacher at St. Andrews school and his class clearly depicts that problem:

Teacher:	<i>What causes the stone to fall?</i>
Pupil 1:	<i>The force pulls the stone towards the earth.</i>
Pupil 2:	<i>The force pulls the stone.</i>
Teacher:	<i>How do we call this type of force which causes objects to fall towards the earth?</i>
Pupil:	<i>Gravitational force.</i>
Teacher:	<i>What generally makes things fall?</i>
Pupil:	<i>Their weight</i>
Teacher:	<i>Why does the stone not fall when I suspend it in the air by means of the string?</i>
Pupil:	<i>It is being stopped by something.</i>
Teacher:	<i>Who can tell me what that something is?</i>
Pupils:	<i>(No response)</i>
Teacher:	<i>Is the weight of the object still acting on it?</i>
Pupils:	<i>(No response)</i>

The other problem was that the students tended to associate force with motion. In the exercise illustrated above, students consistently denied action of any force(s) on the scale pan as long as the wooden block remained stationary. Similarly, when asked if a student pushing a wall was applying force, the answers in all classes consisted of "Yes" and "No". Those who answered "No", on each occasion, argued that there was no force because the walls were not moving. Because of these problems, the original lesson plan was modified by allocating more time for explaining the concept of weight to the students. Also, a game of tug-of-war was included as one of the class activities to help students internalize possible frameworks that two forces acting in opposite directions could generate.

Despite the additional time revising the concept, students' difficulties in relating weight to other forces acting on bodies in equilibrium (e.g., a book resting on a table or an electric bulb

suspended by a flex in the ceiling) persisted. On the other hand, all case study teachers in the three research schools told the researcher that the tug-of-war exercise helped students to gain better understanding of the ideas that two forces acting in opposite directions might (or might not) produce motion depending on their magnitudes, and that the absence of motion did not necessarily mean the absence of force(s) in action. There might be resistance such as one team of the tug-of-war resisting being pulled by the other team.

Lesson 4

In Lesson 4 students were taught simple explanations for some everyday life phenomena involving an understanding of the concept of force. Even though students from the three research schools were familiar with examples selected by their respective teachers, it was only at Bo school that scientific explanations for some of the examples were offered by the students. Nevertheless, students from the three schools showed great enthusiasm in this lesson, possibly because they could relate what they were learning to real life situations. At Bo school, the teacher discussed with his class the uses and effects of frictional force. The following were recorded as key points of that discussion:

1. *Frictional force enables us to walk. Less friction between the soles of our feet and the ground surfaces makes it difficult to walk on polished surfaces.*
2. *The surfaces of vehicle tyres are made rough in order to increase the friction between the tyres and the surfaces.*
3. *Friction can cause wear and tear and produces heat. Lubrication of machine parts is to overcome this problem.*

7.3 SUMMARY

The present chapter has presented illustrative examples of the action research programme through its developmental and trialling phases. In the next chapter an analysis is made from the action research of the general; themes that emerged, together with a description of attitudinal and behavioural changes made by the Case Study teachers and their students as a result of their experiences.

CHAPTER 8: RESULTS: OVERALL IMPACT OF THE SCIENCE FOR ALL CURRICULUM

Chapter Seven provided an ongoing picture of the behaviour of the case study teachers as they came to understand and be able to implement the Science for All curriculum. The present chapter highlights the main trends in the teachers' behaviour, describes changes in their perceptions about science teaching, and discusses the impact of the new curriculum on student attitudes.

8.1 EMERGING TRENDS FROM TRIALLING OF THE NEW CURRICULUM

During trialling of the two packages on Measurement and Force, certain trends emerged in the case study teachers' attitudes, skills, and knowledge of the new curriculum that needed *in situ* treatment. These were mostly to do with:

1. Doubts
2. Clarification
- 3 Skill deficit
- 4 Mind load
5. Confidence
6. Changing role for the teachers

Details of these themes are discussed in the following sections.

8.1.1 Doubts

Even though the teachers from the case study deliberations supported the idea of a change in the General Science curriculum, there were signs of apprehension in their suggestions during the first week of the inservice training programme. In particular, they were sceptical about the practicability of grounding the teaching and learning of General Science in students' everyday experiences without lowering the content of the subject. The case study teachers' concern reflected the misconception held by many people who use Science for All to mean

'watering down' the content of science (c.f., Munby and Russell, 1987). Such a programme, the teachers warned, would be met with opposition both from the school authorities as well as parents, since it would not provide the students with equal opportunity to pass public examinations.

Clearing the doubts of these teachers presented the researcher with two tasks. Firstly, there was the need to convince them about the advantages of grounding junior secondary school science education in the learners' real life experiences. The second task was to help these teachers understand from first hand experience that such a programme at the junior secondary school level did not necessarily mean 'watering down' the content of the scientific concept taught.

In connection with the first task, it will be recalled that the aim of some of the working papers that were presented by the researcher during the first week of the inservice training programme was to familiarize the case study teachers with the advantages of the Science for All Curriculum, especially grounding the teaching and learning of school science in learners' real life experiences. In addition, the researchers' exploration with the case study teachers of the topic context for teaching both Measurement and Force, clearly demonstrated to these teachers how divorced school science usually was from the students' real life cultural practices. That strategy helped to establish a consensus among the case study teachers about the need to integrate school science with students' everyday experiences in their traditional culture outside school.

To overcome the second task, during the entire trial exercise the researcher ensured that lesson plans covering the two units on Measurement and Force were prepared by the case study teachers themselves, emphasising aspects of the topic content they wished to cover. For most of the time, the researcher advised only on matters relating to teaching method, the amount of material to be covered per lesson, and linking the content of a particular lesson to real life examples. Thus both the content and the quality of what was taught on the two topics were under the jurisdiction of the case study teachers. The effects of these treatments on the case study teachers' initial

doubts can be inferred from the following views expressed by some of the teachers during and after the trialling exercise.

During one of the after-trial interviews with the researcher, the case study teacher of the unit on Measurement at the St. Andrews school stated:

I did not know before that the purpose of teaching science was to enable students to apply the ideas they are taught in everyday life. To me, science lessons were some sort of packages, collected from textbooks and handed over to students.

Another case study teacher endorsed this view by reporting that in the past he had used textbook examples which were unfamiliar to both himself and his students to describe scientific processes in General Science classes. Yet both of these teachers reported not using any textbook during the trialling of the new curriculum materials.

Apart from the advantage of making the case study teachers less dependent on textbooks, grounding the teaching of General Science in real life examples also minimized these teachers' total dependence on stereotyped laboratory sessions for science practicals. The Head of Science at Bo school reported that before the trial project, teachers used to ask him quite often for materials from the laboratory to teach General Science in Forms 1 and 2. He observed that requests from those teachers were minimal during the trial of the new curriculum materials. The teachers at Bo school supported this observation by their Head of Department. They reported that they didn't need laboratories *per se* to teach the new curriculum materials, and that the environment provided them with sufficient material to engage students in practical activities. They stressed this particular aspect of the new curriculum as an important feature since many of their colleagues believed that science practicals could only be thought of as laboratories. All the case study teachers agreed that the materials covered on the two topics were adequate for the respective form levels, thus demonstrating diminution of their initial doubts.

8.1.2 Clarification

Another theme that emerged during the trial exercise had to do with clarification of the case study teachers' ideas on certain facets of the new curriculum. These were mostly to do with elicitation of students' prior ideas on the topics, linking the topics to the students' everyday experiences, and developing the right techniques to correct students' prior misconceptions about the topics.

Progressive trial results from both units unveiled difficulties encountered by the case study teachers in implementing their theoretical understandings of these components about the new curriculum in practice. For example, allocation of limited time for brainstorming of students' ideas, or planning lessons centred around classrooms, were illustrations of some of these gaps. This necessitated constant clarification of these problems by the researcher as they emerged during the trialling exercise. The techniques employed for these clarifications are described under the next theme which was related to the present one.

8.1.3 Skill Deficit

Development of the appropriate skills to teach by the conceptual change method was another problem that confronted the trial exercise. Because the case study teachers were not accustomed to using students' ideas in teaching science, they encountered considerable difficulties soliciting information from the students to sustain class discussions during the first trial lessons on Measurement. This problem was also compounded by the nature of the students. To illustrate, discussions between the researcher and the case study teachers about poor participation by students during the first trial lessons revealed:

1. Although English is the official language of instruction, by the time they start secondary school many students are not fluent in English and indeed it is their second language. Because students tend to mock their mates who speak bad English in class, most children shy away from coming forward with their ideas.
2. The system of Western education has debased the indigenous norms, often describing traditional beliefs as primitive. Consequently, students are ashamed to communicate openly the traditional beliefs they hold that are contrary to western beliefs.

3. School science is largely perceived as something western. Students do not therefore conceive of local examples as being scientific to be put forward in science lessons.

These problems, coupled with the case study teachers' own deficiencies to elicit ideas from students, resulted in the first trial lessons being rather teacher-centred. One of the case study teachers in the unit on Measurement made the following remarks after his trial of Lesson 1 :

I felt myself being dragged towards the Chalk-and-Talk method. I ended up doing all the talking since not much was coming from the students.

Various strategies were formulated during the course of the trialling to overcome the problems outlined above, and also that of teaching the case study teachers how to elicit information from students to sustain class discussions. Problems 1 and 3 were composite and needed the same treatment, namely, development of the right questioning techniques to probe students ideas and make these ideas public. To overcome the problem of English grammar, it was agreed that during starter activities, teachers should encourage students to write their ideas on paper. The teacher would then go around the class sampling the various ideas, reading them aloud while making the necessary grammatical corrections if any. This technique was demonstrated to the case study teachers by the researcher during the retrial of Lesson 1 in Measurement. The full account of that retrial lesson was reported in Chapter Seven.

To further help the case study teachers improve their questioning techniques, the researcher constantly ensured that they wrote down sample questions on every lesson and rehearsed these questions with him during their weekend meetings. During these sessions, stereotyped, authoritative questions like *"Who can define measurement for us?"* or *"How do you define force?"* were modified to read *"Can you explain what you understand by the word measurement?"* or *"Who can describe in his/her own words the meaning of force?"* The sequencing of these questions was also looked at during those meetings.

To illustrate this point, the case study teacher of the unit on Force at the school at Gerihun formulated the following questions to solicit students' explanations on why objects fall:

- Q1. *How many of you have heard about the phrase gravitational force before?*
- Q2. *What does it mean?*
- Q3. *If I let this stone free in the air why does it fall?*

After negotiating with the teacher, the sequencing was altered to flow as follows:

- Q1. *What makes the stone fall if I let it free in the air?*
- Q2. *Why do objects generally fall?*
- Q3. *How do we call that something which causes objects to fall?*

The two techniques enhanced the case study teachers' ability to elicit information from the students. At the end of the trialling of the new curriculum materials, one of the case study teachers made the following comment:

Previously students were not encouraged to expose their ideas. But this time, having participated in this study I exercised more patience trying to extract from them their prior ideas.

The extent to which the case study teachers came to appreciate students' prior ideas is summed up in the following remark by one of them:

We learnt a lot from the students' ideas. In fact I will now be using students' prior ideas in teaching Agriculture.

To tackle the second problem which had to do with belief patterns also required special skills. For instance, despite forewarning that there were traditional beliefs that inhibited Sierra Leonean children from measuring their heights, the case study teacher at Bo school forgot to make use of that fore-knowledge to dispel the fear among students.

After the first trial of Lesson 3, the teacher reported to the researcher thus:

I wanted to engage the class in as many measuring activities as possible, but I noticed some fear in the students when I asked them to measure their heights.

To dispel such beliefs, the case study teachers were advised to always bring to the class consciousness the existence of such beliefs or misconceptions. They would then try to alter those beliefs or misconceptions either by role modelling, or confronting the students with the scientific explanation of the particular concept.

One teacher, in his retrial of that lesson, brought up the issue of traditional beliefs not measuring peoples' heights. Some students acknowledged having heard about the belief before but claimed not to believe it. Ironically, these same students told the teacher that they had not measured their heights before. The teacher next tried to convince the students why that belief was not correct by citing instances wherein peoples' heights were being measured everyday. As one of the measuring activities, he asked the class to make a chart of the heights of all the members of the class starting with him. There was no sign of fear among the students this time. The other case study teacher at the St Andrews school who employed the same approach for his first trial of Lesson 3 went to the extent of asking the students to measure and bring to the next lesson the heights of the members of their households. This assignment was carried out by the students, and the teacher spent part of Lesson 4 'playing around' with the results (e.g., comparing the heights of all the fathers).

Role modelling was not applicable to correcting students' misconceptions of the concept of Force. However, students were confronted with the correct frameworks of force like the examples described in Lessons 2 and 3 above. In addition, the teachers in the three research schools engaged the students in activities such as identifying common types of forces in everyday activities as a way of reinforcing the newly learned concept.

8.1.4 Mind Load

A further theme that emerged from the trial exercise concerned the amount of content material the teachers wanted to cover during lessons. It was explained in Chapter Six that as a result of the emphasis placed on public examinations, science teachers 'dash' through subject syllabuses using the fastest methods. This tendency was manifested during the initial stages of the trial exercise. At the beginning of the trialling, both groups of case study teachers were over-zealous in trying to cover as much content material as possible for each lesson. Discussion of the lesson plans by the researcher during the weekend meetings greatly minimized this problem and it gradually disappeared as the trial progressed. Subsequently, the time to teach the unit on Measurement which used to be four periods of forty minutes each was doubled. Asked whether the additional teaching sessions affected the school programme, one of the case study teachers replied in the negative. He informed the researcher thus:

Participation in this study has helped us to realize that teaching is not only covering lots of topics. But the understanding the students will have about the topic and the interest they will develop is more important. At the junior secondary school level, it is not how much we cover but what the pupils are able to learn.

8.1.5 Confidence

It was reported in Chapter Six that many case study teachers, because of their subject specialties, 'skipped' the Physics section of the General Science syllabus. These teachers confessed lacking the confidence to teach Physics topics even at the junior secondary school level. This disability was evident among the case study teachers for the unit on Force during the initial stage of the trial. These teachers were not as confident as their counterparts with the unit on Measurement in handling the new curriculum material. Unlike the teachers of the unit on Measurement who took greater responsibility for directing their lesson plans right from the outset, those in the unit on Force needed support from the researcher during the initial stage of the trialling before they could take off on their own. The kind of support that was provided for these teachers was mostly professional, involving 'brushing up' their knowledge of the

scientific frameworks of force, and planning the type of practical activities in which to engage the students.

The researcher also learnt that the confidence of these teachers was undermined by being conscious of their inability to solve numerical problems on Physics topics, which was an aspect that was stressed in the old General Science syllabus. The fact that the new curriculum did not emphasise numerical problems on the topic, gradually helped to reduce the initial fear of those teachers. However, in spite of this and the additional attention from the researcher, one of the three case study teachers never really felt at ease.

8.1.6 Teachers' Roles

It became obvious from the trialling exercise that successful implementation of the new curriculum materials required changing roles for the science teachers. Apart from being a planner, guide, manager and facilitator, the teacher had to have the ability to identify examples from the environment that were relevant to a particular concept taught, and be able to use such examples as a springboard for introducing that concept in science class.

During the trial, it was difficult for the case study teachers to fill these particular roles, perhaps because of the newness of it all to them. They had most difficulty, for example, with planning real-life links to illustrate frictional and tensional force. The tug-of-war example mentioned in Chapter 7 was the researcher's idea. Similarly, it was the researcher who taught these teachers how to use the principle of a hanging hammock to exemplify tensional force.

8.1.7 Summary

Trial results showed that adoption of an innovative teaching approach by the case study teachers was a complex matter. It required guidance from the researcher to minimize problems that emerged during the trialling, specifically those to do with doubts, clarifications, skill deficit, confidence, and teachers' changing roles. However, given appropriate guidance, the teachers were eventually convinced about the superiority of the constructivist Science for All curriculum model for better understanding and meaningfulness of the junior secondary school

science. For example, as a result of their interaction with the new curriculum, the teachers showed evidence of becoming conscious about the incorrectness of the 'bucket image' of science which many science teachers are believed to hold. For these teachers, recognizing the importance of students' prior ideas in teaching and learning science was only realised after their interaction with the new curriculum.

However, elicitation of these prior ideas from the students was one of the challenges that confronted the teachers during the trialling of the new curriculum materials. It became evident that many of the students were not willing to 'put across' their ideas. In addition to the factors listed before (see p.157), the failure of these students to 'put across' their ideas may be a consequence of their outlooks to ways of acquiring knowledge. It was reported in Chapter Two that the acquisition of new knowledge for children from a traditional culture consisted of transmission of facts from elders such as teachers. Ways of overcoming this handicap are crucial if the conceptual change method of teaching science is to succeed in these societies.

Finally, the point was made in Chapter Two that one of the unresolved issues surrounding the Science for All curriculum movement had to do with selection of the content topics. Differences in views as to what should constitute the content of Science for All curricula was highlighted in that chapter. The present study tried an alternative content topic selection structure in which discipline-focused topics like Measurement and Force were linked to the real life experiences of the learners to develop instructional guides for teaching these topics. Trial results discussed in this chapter showed satisfaction among the case study teachers with this structure. According to these teachers, the approach posed no threat of lowering the standards of the General Science syllabus content.

8.2 IMPACT ON THE TEACHERS

This section discusses the impact of the action research experience with the Science for All type of curriculum and the case study teachers' perceptions about:

1. Curriculum in General Science - aims and objectives

2. The nature of science and ways of acquiring scientific knowledge
3. Methods of teaching science
4. The appropriateness of school science for community living

8.2.1 Curriculum in General Science : Aims and Objectives

It was reported in Chapter Six that science teachers' perceptions about the aims, objectives and content of the General Science curriculum were similar to ideas borrowed from science programmes or textbooks developed for western countries. Furthermore, these teachers saw validity in tying the science curriculum strictly to the requirements to pass national examinations. Such views seemed to have been altered following the teachers' interaction with the new Science for All curriculum. In one of the group discussions, for example, a case study teacher distinguished the new curriculum from the old one as follows:

Before, we were using the old syllabus for one purpose only - preparing students for public examination. In the new curriculum, apart from preparing students for examinations alone, we also emphasized other aims such as helping students to relate what they learn in science to their everyday activities.

Another teacher observed:

In addition to preparing students for examination, we have also incorporated other considerations which are beneficial to even students who are likely not to complete secondary school education. Like the material I taught in Measurement. Students can use these ideas in a variety of situations - like in the kitchens, shops, hospital and even on the farms.

The reason why the teachers had not incorporated such considerations before was explained by another teacher as follows:

I never had clear ideas about the aims and objectives of the General Science curriculum. I only learnt that through participation in this study.

This view appeared to be the consensus among the case study teachers, all of whom had earlier expressed dissatisfaction with their preservice training programmes. Asked what they then perceived to be

the aim of General Science after their participation in the present study, one of the teachers replied:

Knowledge of General Science should help pupils to improve their standard of living.

As one case study teacher put it:

This inservice training has refocused our thinking in terms of what our commitments are for the students we teach

These kinds of statements suggest a change process wherein the case study teachers were becoming aware of setting aims and objectives for General Science curriculum that were attainable and meaningful to the majority of their students. Such is the ideal of the Science for All curriculum movement, an ideal the researcher wished to engender among science teachers in Sierra Leone.

8.2.2 Nature of Science and Ways of Acquiring Scientific Knowledge

An adequate conception of the nature of science is considered to be a distinguishing attribute of the scientifically literate individual. It is also believed that a teacher's conceptions influence his/her teaching behaviour, and that improved student conception will, therefore, necessarily follow improved teacher conception (Lederman and Zeidler, 1987). Consequently, most teacher development programmes now focus on improvement of teachers' conceptions as a way of bringing about secondary school students' understanding of the nature of science. The present study was no exception to this position.

Following findings that the case study teachers lacked understanding of recent views on the nature of science and ways of acquiring scientific knowledge (see 6.3, p.111), providing these teachers with the appropriate views was one of the objectives of the action research. Instances reported earlier in this chapter of teachers acknowledging the importance of students' prior ideas for teaching and learning new topics in science marked the beginning of the change process in the teachers' outlooks. One teacher informed the researcher:

We found out that students have ideas about science even though some of these ideas are vague.

The teacher explained what he meant by vagueness as follows:

Students apply knowledge of force in everyday activities like running. They maintain balance by slowing down when negotiating curves, or they do not stop abruptly when coming to a halt.

The problem according to this teacher was that:

Students cannot explain these activities and science teachers had in the past not related these experiences to their science lessons.

Asked how scientific knowledge could be acquired, another teacher responded:

At the junior secondary school level, acquisition of scientific knowledge should be through rectification of students' prior ideas.

Yet another teacher stated that the process should be "one of correcting or reinforcing children's conceptions".

Even though science teachers' beliefs may not necessarily be reflected in their classroom behaviour (Karnphanit, 1986), the above statements seem to indicate a major shift in the case study teachers' outlook on the nature and ways of acquiring scientific knowledge. It will be recalled that before the action research, these teachers held the absolutist view of science.

8.2.3 Methods of Teaching Science

Results of the case study investigation revealed that the 'chalk-and-talk' approach to teaching was identified as the commonest method employed by the case study teachers. Whereas the teachers justified their choice of the method in terms of examination pressure, the researcher interpreted the act as the teachers' lack of understanding of a philosophy of teaching science. The change in these teachers' perceptions about methods of teaching science after being confronted

with recent views on the nature of science tended to support the researcher's interpretation.

For example, one of the outcomes of the new curriculum was the impact it made on the case study teachers' understanding and appreciation of the conceptual change approach as a more appropriate method of teaching science. After the trialling, one of the case study teachers described science teaching as comprising the following process.

Encourage students to come up with their own ideas or understanding about the topic. After that, argue out things to help the students see the idea from the scientific point as a way of rectifying their previous ideas. Make frequent evaluation to see if the students still adhere to their previous ideas.

In addition to developing a 'feel' for the conceptual change method as demonstrated above, the teachers also appeared to have begun a process of developing their own theories about teaching science. According to one of the teachers:

There is no unique method of teaching science. Science teachers should be flexible because for certain concepts, some prior explanation is needed.

Such pronouncements convinced the researcher that the case study teachers were actually assimilating the change process in which they were involved. It was not just a matter of blindly accepting whatever they were told by the researcher. Otherwise, they would have just proclaimed the conceptual change approach as the best method of teaching science since that was the method emphasized by the researcher during the trialling.

8.2.4 Appropriateness of the Junior Secondary School Science for Community Living

This was the outcome that was least investigated by either the case study teachers or the researcher. Because of circumstances beyond their control (e.g. workload, students being boarders or staying far away from the teacher), both researcher and the case study teachers were not able to monitor the effects that the new curriculum was having on the learners' communities. Only one teacher delightedly informed the researcher during the final evaluation meeting about a

student who reported using the foot-spacing technique they were taught in school to estimate the distance between his village and a neighbouring one.

8.2.5 Unanticipated Outcomes

In addition to the above mentioned effects, other professional development attributes were noticed in the case study teachers that were unanticipated. The three most obvious ones were: attitudes towards team work, the teachers' image of themselves as researchers; and mastery of subject matter.

At the beginning of the present research, there was no evidence of team work among General science teachers in the three research schools. At Bo school, individual teachers occasionally consulted the Head of Department: probably because his subject speciality was Physics, which the case study teachers in that school confessed they found difficult to teach. At the other research schools where the subject speciality of the Heads of Departments was Biology, no such consultations were observed or reported by the respective Heads of Departments.

Team work among the case study teachers seemed to emerge unconsciously as an outcome of the teachers' interaction with the new curriculum materials. By the end of the trialling exercise, the teachers had developed team work spirit to the extent that they could organize a meeting among themselves to plan strategies for teaching new lessons. Even teachers who were not part of the research team, but were teaching General Science in the other Form 1 and 2 streams in these schools, gradually got involved in the team work. Furthermore, as the trialling progressed the researcher observed that the teachers were becoming more open minded about problems they encountered in their classrooms. Discussing such problems openly in staff rooms was becoming a common practice for the case study teachers, a practice that did not exist before.

The other positive outcome of the case study teachers' interaction with the new curriculum was the teachers' image of themselves as co-researchers. It became evident that the case study teachers in this study regarded themselves as researchers rather than just recipients

or 'triers' of the researcher's ideas. Phrases like "our work, the curriculum we have developed, our new curriculum" were identified as common descriptors the case study teachers used to refer to the new curriculum. The researcher found this outcome important because, even though teacher participation in curriculum development is widely advocated, the idea is rarely implemented in many African countries.

Another unintended outcome in the teachers' professional development had to do with subject mastery. Even though only one topic in Physics was covered at either Form 1 or 2 level, the Form 1 case study teachers in particular, appeared to have acquired skills that would enable them to teach physics topics more confidently. At the end of the trial, one of these teachers reported to the researcher:

*Previously, I didn't like teaching topics on Physics.
Now I am boastful of handling these topics for which I
previously held negative attitudes.*

The Head of Science at Bo school reported that one of his staff who had problems teaching Physics before the action research, expressed satisfaction with his progress using the new curriculum material.

8.2.6 Summary

This section sums up the effects of the new curriculum on science teachers' outlook on the junior secondary school science programme in Sierra Leone. Results discussed so far tend to suggest that the case study teachers' understanding of the aims and objectives of the General Science curriculum, as well as the nature and ways of acquiring scientific knowledge, were enhanced following interaction with the new curriculum material. In particular, the teachers became conscious of designing aims and objectives for General Science curriculum that were meaningful and attainable for the majority of their students. The teachers exhibited evidence also of acquiring methods of teaching science that took recognition of learners' prior ideas. Other positive impacts of the new curriculum noted were the teachers' acquisition of skills to investigate their own classroom teaching, and their support for a shared approach to planning.

In conclusion, results of the action research exercise showed that the sample of teachers found the ideas of the Science for All curriculum appealing and applicable in the Sierra Leonean context.

8.3 IMPACT ON STUDENTS' ATTITUDES TO SCIENCE

The impact on students' attitudes of the new Science for All curriculum was addressed, in part, by the remarks of their teachers as discussed in Section 8.2 above. In addition, however, the researcher used the attitudes to science questionnaire as a kind of pre- and post-test instrument. This procedure was described in the Methodology Chapter (see 4.5.1, p.68).

Pre- and post-test questionnaire data for Form 2 students who experienced the new curriculum from two of the research schools (Bo and St. Andrews schools) were analysed statistically using the same procedures as were used in the large sample survey (see Chapters 4 and 5). Thus, comparisons were made for Form 2 students who had experienced the new curriculum and those who have examined the old curriculum in the previous academic year. Within this comparison statistical analyses sought to identify any main effects for the variables of time, class streams and school, together with any interaction effects for these variable.

In the interest of readability, the statistical analyses are not reported here in detail. Such analyses may be found in APPENDIX 8.1. Reported in the present section are the main trends only.

8.3.1 Time

No significant differences for any of the seven science-related attitudes scales were identified for this factor either within the Bo or the St. Andrews schools or between the two schools taken together. This seems to suggest that on the whole, students' attitudes towards science were not enhanced after interaction with the new Science for All curriculum.

8.3.2 Class Streams

The multivariate tests revealed significance for the Class Streams variable in the case of Bo school only and on one scale only - Enjoyment of Science Lessons (See TABLE 8.1). According to that table the Stream 3 students of Bo school showed significantly greater attitudinal enjoyment of science lessons than the Stream 1 students. They also showed a greater enjoyment than the Stream 2 students but this result only approached significance. Despite statistically significant findings on this scale, however, in everyday terms the magnitude of difference among the means was not really large.

TABLE 8.1 Mean Score Comparisons for the Factor Class Streams
(Bo School, N=218)

<u>Enjoyment of Science Lessons Scale</u>	
Streams	Mean Scores
1	20.2
2	20.0
3	22.1

8.3.3 School

Analyses here showed that students at the St. Andrews school scored significantly higher means in the post-test than students at Bo school on six of the seven science-related attitudes scales. The one scale in which there was no significant difference was the Understanding of the Nature of Science (see TABLE 8.2).

TABLE 8.2 Post Mean Score Difference Between Bo and St. Andrews Schools

S C A L E	M E A N S	
	Bo School (N=218)	St. Andrews School (N=104)
1. Application of Scientific Knowledge	21.9 ¹	23.2 ²
2. Understanding the Nature of Science	25.6 ¹	25.6 ¹
3. Attitudes to Inquiry	23.6 ¹	27.9 ²
4. Adoption of Scientific Attitudes	21.9 ¹	24.6 ²
5. Enjoyment of Science Lessons	20.5 ¹	23.9 ²
6. Leisure Interest in Science	19.7 ¹	23.1 ²
7. Career Interest in Science	21.0 ¹	24.6 ²

Note: Means scores in the same row carrying different index numbers are significantly different by ANOVA F tests ($p \leq 0.01$)

The differences in mean scores between the two schools should not be taken to imply that students at St. Andrews school reacted more positively to the new curriculum than students at Bo school. (It was observed in the large attitudes survey that students at St. Andrews school scored significantly higher means than students from Bo school on these same six scales - see Chapter 5).

8.3.4 Time by Class Streams

The multivariate tests of significance showed the variable time by class streams was significant for three scales in the case of St. Andrews school only, but none for either Bo school or the two schools taken together. The three scales were Understanding the Nature of Science, Adoption of Scientific Attitudes and Enjoyment of Science Lessons (see TABLE 8.3).

TABLE 8.3: Comparison of Mean Scores Between St. Andrews School Students of the Old and New Curricula for the Factor Time by Class Streams (N=104).

<u>Understanding the Nature of Science Scale</u>		
Streams	M E A N S C O R E S Old Curriculum	New Curriculum
1	23.8 ¹	25.8 ¹
2	28.9 ²	24.6 ¹
3	25.5 ¹	23.4 ¹
<u>Adoption of Scientific Attitudes Scale</u>		
1	24.5 ¹	22.5 ¹
2	23.0 ¹	26.1 ²
3	27.6 ¹	26.2 ¹
<u>Enjoyment of Science Lessons Scale</u>		
1	24.9 ¹	23.4 ¹
2	21.6 ¹	24.3 ¹
3	27.6 ¹	23.5 ¹

Note: Mean scores in the same row carrying different index numbers are significantly different by Student Newman-Keuls ($P \leq 0.05$).

The table shows no linear pattern of change in mean score differences between the two categories of class streams on these three scales. For example, whereas the stream 2 students of the old curriculum scored significantly higher means than their peers of the new curriculum on the Understanding of the Nature of Science scale, the reverse picture was true for the Adoption of Scientific Attitudes Scale. With the Enjoyment of Science Lessons Scale, differences in mean scores between students who studied the old and new curricula were not significant. It is important to note that although none of ANOVA comparisons between mean scores for these two groups were significant on this scale, the differences fell short of significance for both streams 2 and 3 students.

8.3.5 School by Time by Class Streams

Analyses showed that the factor school by time by class streams was significant for three scales: Application of Scientific Knowledge, Attitudes to Inquiry and Enjoyment of Science Lessons (see TABLE 8.4).

TABLE 8.4 Comparison of Mean Scores on Scales for Which the Factors School by Time by Class Streams were Significant

<u>Application of Scientific Knowledge Scale</u>		
	M E A N	S C O R E S
	Old Curriculum	New Curriculum
<u>Bo School</u>		
Streams 1	20.9 ¹	21.3 ¹
2	23.6 ²	20.9 ¹
3	21.4 ¹	24.4 ¹
<u>St. Andrews</u>		
Streams 1	23.7 ¹	23.9 ¹
2	21.8 ¹	23.1 ¹
3	25.5 ¹	22.8 ¹
<u>Adoption of Scientific Attitudes Scale</u>		
<u>Bo School</u>		
Streams 1	20.5 ¹	21.6 ¹
2	22.4 ¹	22.6 ¹
3	21.4 ¹	23.7 ²
<u>St. Andrews</u>		
Streams 1	24.5 ¹	22.5 ¹
2	23.0 ¹	26.1 ²
3	27.6 ¹	26.2 ¹
<u>Enjoyment of Science Lessons</u>		
<u>Bo School</u>		
Streams 1	19.7 ¹	20.6 ¹
2	20.5 ¹	19.6 ¹
3	21.3 ¹	22.9 ¹
<u>St. Andrews</u>		
Streams 1	24.9 ¹	23.4 ¹
2	21.6 ¹	24.3 ¹
3	27.6 ¹	23.5 ¹

Note: Mean scores carrying different index numbers in the same row are significantly different by ANOVA of simple main effects ($P \leq 0.01$).

The mean score difference displaced in the table once again revealed no consequence in the pattern of change across variables. For example, the Bo school Stream 2 students of the old curriculum scored significantly higher means than the Stream 2 students of the new curriculum on the Application of Scientific Knowledge Scale. With the Adoption of Scientific Attitudes Scale, it was the St. Andrews' Stream 2 students of the new curriculum who scored significantly

higher means than their peers of the old curriculum. Once again, even though the multivariate tests were significant for the Enjoyment of Science Lessons Scale, the ANOVA tests did not reveal any significant differences between mean scores for any of the streams across the two schools.

Having reported these results, it should be noted that differences between means were minimal (hardly more than a magnitude of 4), suggesting that for educational purposes, the new curriculum had not made the anticipated impact. Hypothetically, Streams 2 and 3 classes of students of the new curriculum from the two schools could be expected to score meaningfully higher means than their counterparts who studied the old curriculum. Those were the streams of classes used for the trial and retrieval lessons during the action research.

8.3.6 Summary

The above analyses revealed interaction effects between the factors time by class streams for the individual schools, and for school by time by class streams for the two schools taken together. But while the interaction effects were statistically significant, the pattern of changes in mean scores for the variables concerned were not consistent enough between the two schools to provide any logical interpretations. Thus, the observed interaction effects could be attributed to the multifarious problems associated with teaching and learning, and not necessarily an outcome of the students' interaction with the new curriculum.

The results revealed further that post-test mean scores for students at the St. Andrews school were significantly higher than those of students at Bo school. But as noted earlier, the differences in mean scores could possibly be due to differences in school cultures rather than to an effect of the new curriculum. St. Andrews, like other coeducational schools, scored significantly higher means than single sex boys' schools (e.g. Bo school) in the large attitudes to science survey on all but the Understanding of the Nature of Science Scale.

In general, however, though statistically significant, the mean score differences on those variables were minimal in educational terms. More importantly, the results showed that, on the whole, the differences in mean scores between students who studied the new and the old curricula were not statistically significant on all of the seven science-related attitudes scale. This indicates that interaction with the new curriculum did not lead to students developing more favourable attitudes towards science.

It should be remembered, however, that results here stem from one questionnaire and should be interpreted also in the light of the teachers' impression which were positive. One of the teachers exemplified the positive impact of the new curriculum on students' attitudes by informing the researcher that:

When you enter my science class you find pupils measuring the ear sizes, heights etc. of their peers. The children have developed this attitude of measuring things on their own.

Another teacher provided evidence of the positive changes in students' attitudes towards science by noting that:

Even the way pupils are behaving in class shows signs of positive change in their attitudes towards the subject. The classes are far more lively these days than before.

Furthermore, failure of a new curriculum material to produce positive effects on students' attitudes towards science is not unique to the present study. Brown (1978) claimed that comparative studies have given little indication that new curricula are superior to traditional courses. She reported that studies of pupils' attitudes show that they are usually either the same, or less favourable, after the new courses than they were before. One example of such studies was by Meyer (1970) who investigated pupils' reactions to the Nuffield Science Teaching Project Trial Materials in England. Results of that investigation revealed that Nuffield science had limited success in improving scientific attitudes and interests among boys in particular.

CHAPTER 9: SUMMARY AND IMPLICATIONS

This study was designed to investigate an educational change process through introducing science teachers in Sierra Leone to an innovative approach to the teaching of science at the junior secondary school level. The concern was to help the teachers develop a science curriculum in school that would have transfer to the everyday lives of the students in their traditional village settings. Lack of such transfer is a recurring problem at present.

The study began with the examination of science teachers' prior perceptions about the junior secondary school science programme. This was by means of interviews and classroom observations of General Science lessons of selected science teachers, sampled from schools in and around Bo in the southern province of Sierra Leone. An intervention phase followed in which the selected teachers were introduced to the ideas of a constructivist-based Science for All curriculum. Subsequently, an action-research programme involved these teachers in working with the researcher to develop and trial teaching packages in Physics based on the Science for All curriculum.

The main thrust of the study, was to investigate the effects of the teachers' interaction with the new curriculum on their own professional development. In addition, an attitudes to science questionnaire was administered as pre- and post-test instruments as one way of investigating the impact of the new curriculum on students of these teachers. The attitudes to science questionnaire was administered to students of provincial towns to ensure that the values obtained from the pre- and post-tests were to some extent representative of Sierra Leonean students.

This final chapter attempts to summarise and consider some implications of the research findings, and make recommendations for further research on science curriculum innovation in Sierra Leone.

9.1 LIMITATIONS OF THE RESEARCH DESIGN

The main limitation of this study concerned sample size and selection. In order to keep the study manageable within the constraints that confronted the researcher in the field, only eight science teachers were selected from schools in and around one district Headquarter town to constitute the sample teachers. Similar managerial considerations prevented the use of random sampling to select sample schools for the large sample attitudes to science survey. For reasons of accessibility, schools were selected from the Headquarter towns in three of the four Provinces in Sierra Leone. These sample size and selection factors, then, mean that caution must be exercised in generalising too widely from the findings of this study.

Another constraint on the study was the limited time available to the researcher to monitor the trialling and evaluations of the new curriculum materials. Since the proposed curriculum is a two year course, the ideal situation would have been a longitudinal evaluation study at regular intervals covering the two year span. The nature of the present study could not permit that. Therefore, the trial results based on two topics only should once again be treated with caution.

At the time of the research design the researcher felt satisfied with the two main instruments that were used for data collection : interviews and the attitudes to science questionnaire. Upon reflection, however, the researcher would have opted to use other instruments to augment those two.

The fact that six of the participating teachers knew the researcher from their pre-service training days (the researcher then being a lecturer in the secondary school teacher training university) had both advantages and disadvantages. On the good side, it enabled the researcher to easily integrate into the schools' system and win the confidence and support of the teachers. But the familiarity could also have caused the teachers to exaggerate the outcomes of their experiences with the new curriculum to please the researcher. For this reason, it might have been desirable to supplement the qualitative data with some quantitative measures. Alternatively, other personnel could have been employed to monitor the effects of the new curriculum on the case study teachers.

Again, restriction on the researcher's time in the field situation prevented him from conducting interviews with the students to glean more information about their reactions to the new curriculum experience. For this reason, results from use of the attitude questionnaire should be treated cautiously.

9.2 MAIN FINDINGS OF THE STUDY

9.2.1 Impact on Teachers

Many researchers have in the past attributed the poor state of science education in Africa to the high incidence of untrained science teachers (Taiwo, 1975, Cole, 1970, Urevbu, 1984). Results of this study showed that over 70 percent of General Science teachers from the sample schools were trained, although only about one in every twelve of them had Physics or Chemistry background.

Despite the acclaimed qualifications, the science teachers in Sierra Leone did not manifest understanding of recent views of the nature and ways of acquiring scientific knowledge. The views upheld by these teachers on these themes at the beginning of the study were mainly in keeping with the Baconian tradition, which invariably disposed them towards the didactic method of teaching science. The present study results revealed further that what constituted the aims, objectives and content of the General Science curriculum, were mostly ideas borrowed from science education programmes or textbooks developed for western countries. The junior secondary school science programme was portrayed by teachers as lacking a meaningful sense of direction, its main goal being the preparation of students for public examination purposes only. The study showed also that the above shortcomings were spill-over effects of the inadequate pre-service teacher training programmes. These programmes were claimed by teacher educators in science to be over-crowded with too many unnecessary courses.

In overcoming this situation, it was stated earlier that a major problem confronting Science for All kinds of curriculum is the choice of topic-content. The Asian Programme of Educational Innovation for Development (A.P.E.I.D.) recommended linking concept/topic to real

life situations as one way of making the teaching and learning of school science more meaningful to the majority of the learners (U.N.E.S.C.O.-A.P.E.I.D., 1981). Trial results from the present study showed this approach to be viable and acceptable to the Sierra Leonean science teachers. The approach has the special advantage of requiring minimum teacher re-education before implementation, and it poses no threat to those teachers who believed in core discipline-orientated science content.

Furthermore, the conceptual change approach that was employed in the trialling of the new curriculum materials appealed to the case study teachers as a better method of teaching science. The approach enabled them to come to terms with the idea that students had their own understanding about some scientific concepts, be these ideas 'lay' and/or 'gut' sciences (see Claxton, 1984).

In spite of the above, the trial exercise was marred by difficulties that are common to curriculum innovation programmes (e.g., teachers' willingness to adopt the new curriculum, teachers' understanding of the intended curriculum). Techniques employed to overcome some of these problems suggested that establishment of conceptual clarity for the meaning of the innovation appeared to be the essential factor in arousing the case study teachers' commitment. Furthermore, the supportive guidance provided by the researcher throughout the trialling helped the case study teachers to put into practice their theoretical understanding of the change process.

The major impact of the new curriculum on the case study teachers' professional development concerned change in their outlook about the image of the junior secondary school science programme. As a consequence of their action-research experiences, the teachers were able to appreciate recent constructivist views about the nature and ways of acquiring scientific knowledge. Thus they came to support new aims, objectives and methods of teaching General Science, that recognized the importance of building the teaching-learning process on students' prior experiences in real life. These positive changes in the teachers' outlook support findings by Bonnstetter and Kyle (1986) that a well articulated in-service education programme enables teachers to portray a much more positive and exciting image of science.

Other impacts of the new curriculum included the teachers' image of themselves as researchers investigating their own classroom teaching. In addition, the teachers developed a spirit of team work among themselves, planning and discussing common problems relating to their teaching. For some of the case study teachers, experience with the new curriculum trial materials helped them to build the confidence to teach Physics topics which they had previously dreaded.

Positive though the findings above are, the most important aspect of the research was the impact of the curriculum innovation on building conceptual and application bridges between 'school' science and 'everyday' science (i.e. indigenous technology and/or traditional common sense explanations of natural phenomena). The information contained in the instructional guides (see 7.1.5, pp.127-130) identifies how some everyday situations were linked to the two trial topics (Measurement and Force). In addition, accounts of some of the trial lessons highlighted how the topics were abridged to the learners' everyday experiences. Such examples were students' engagement in measurement of the heights of their household members (to dispel fears about measuring peoples' heights) or identification of the types of forces in play in a hanging hammock.

However, in spite of their familiarity with examples of everyday applications of the trial topics, the case study teachers exhibited great difficulties incorporating these examples into their teaching. It was the researcher who constantly reminded them about possible linkages between the topics and their everyday applications.

9.2.2 Impact on Students' Attitudes to Science

Results of the large sample survey of science attitudes suggested that junior secondary school students in Sierra Leone exhibited unfavourable attitudes towards science. Group mean scores for these students on five of the seven science-related attitudes scales were less than 25 (i.e., 50 percent of the maximum possible score on any one scale).

In spite of the overall low mean scores, the results revealed attitudinal differences towards science between different categories

of student. For example, although the differences in magnitudes were not considered to be educationally worthwhile, at the junior secondary school level girls exhibited more positive attitudes towards science than boys. Differences in mean scores between the two groups were statistically significant for attributes that measured student enjoyment of science lesson, leisure interest in science, and career interest in science. As noted before, this finding was inconsistent with previous research, indicating a significantly greater overall scientific orientation among boys than girls, which includes better attitudes towards science (Sjoberg, 1983; Wooley, 1978).

Another difference which was statistically significant, albeit of less magnitude, was that students in coeducational schools displayed more positive attitudes towards science than those in single sex schools. Even though this finding once again did not agree with most others (e.g., The Commonwealth School Commission, 1984), the post-test results proved to be consistent with results of the large sample survey. After interaction with the new Science for All curriculum, students in the coeducational school (St. Andrews) maintained their significantly higher mean scores over students in the single sex boys' school (Bo School) on six of the seven science-related attitudes scales.

The third major attitudinal difference identified about science was one consistent with the literature, that reports a drop in students' attitudes to science with rise in form level (Maddock, 1978; Sullivan, 1979). This trend seemed to have continued in the present study despite the intervention with the new curriculum. Post-test results showed that students' attitudes to science were not enhanced following their interaction with the new curriculum. Mean score differences between students who studied the new and the old curricula were not statistically significant on any of the seven science-related attitudes scales. Nevertheless, the teachers were convinced that the new curriculum had positive effects on their students' attitudes to science. The teachers' judgements were based on students' behaviour which, according to them, showed signs of positive transformation as a consequence of the new curriculum intervention.

9.3 IMPLICATIONS OF THE RESEARCH FINDINGS

Findings in the present study raise pedagogical implications. The point was emphasised in the Literature Review (Chapters 2 and 3) that African children's explanations about most scientific concepts are contrary to those of school science. The citing by Sierra Leonean students of 'police' and 'military' as examples of force in science illustrated the point. Under such considerations, it is logical to conceive of science teaching as a process of conceptual change in which the teacher tries to change the students' alternative conception to a scientific one. Even though the case study teachers from their trial experiences seemed to have developed appreciation of the conceptual change approach of teaching science, there are implications for the content for science curricula.

Bell (1984) cautioned that the conceptual change method of teaching science required time to give students the opportunity to construct, evaluate, accept and use the scientific conception. Trial results from the present study seemed to have proven her right. The time required to teach the units on Measurement and Force were doubled during the trials exercise using the conceptual change method of teaching. While this might suggest that the constructivist method of teaching science would mean a reduction in the number of topics covered in science syllabuses, over a given period of time, this is not necessarily so. Certainly, the present situation of covering too many topics too quickly for the sake of completing examination syllabuses is undesirable. The answer may well be that once both teachers and students are accustomed to the conceptual change approach, units of work on specific topics would be covered faster. Moreover, with several units behind them, students could be engaged more along self teaching/learning lines, and/or including some groups taking responsibility for teaching some topics to other groups - always, however, adopting the constructivist or conceptual change approach. Such suggestions of course would require the support of not only individual school authorities but also the ministry of education, both of which remain wedded at present to the importance of wide topic coverage for public examinations.

Another implication of the conceptual change method of teaching science would be African children's outlook on ways of acquiring

knowledge. Perhaps one reason the indoctrinatory chalk-and-talk method of teaching science has flourished in many African science classrooms is the fact that the method is attuned to traditional African children's outlook that knowledge is given by elderly people, including teachers.

Action-research in the present study found how difficult it was to obtain ideas from students in the third research school in the rural setting. Changing to the conceptual change method, therefore, would require science teachers to acquire the appropriate skills for eliciting information from students. This transformation would require programmes at both the pre-service and in-service levels. To this end, results from the present study showed that a well articulated in-service training could enable science teachers to acquire these skills.

Furthermore, Jegede and Fraser (1989) cautioned that the potential gains derivable from Science for All philosophy might come to naught in non western societies because of students' unfavourable attitudes to science which emanate from socio-cultural factors. If attitudes and achievement are strongly related (c.f. Fraser, 1982; Boulanger, 1981; Malone and Fleming, 1983), then the unfavourable attitudes to science exhibited by junior secondary school students in the present study were also cause for concern.

The unfavourable attitudes to science is not a surprise in the light of the present state of science education at the junior secondary school level in Sierra Leone (see Chapters 2 and 6). Pupils experience conflictual problems because of differences between school science and their traditional life and thought styles, the alienating nature of school science, and the didactic method of teaching, could all be seen as contributing factors to the unfavourable attitudes. Thus, curriculum effort aimed at improving students' attitudes to science should address these problems. Towards this goal, the researcher would support Hewson's (1981) call to make the content of science courses intelligible, plausible and fruitful.

The present study represents one attempt to surmount the problems alluded above. Results of the study revealed that the action research exercise brought vivid realisations upon the case study teachers about

how devoid school science was from the learners' everyday experiences. The exercise also enabled the teachers to identify examples of real life situations that were incorporated in the teaching-learning of the trial topics for better understanding and meaningfulness. These treatments, the teachers believed engendered positive attitudes in their students' attitudes toward science.

Nevertheless, implementation of this idea into actual classroom teaching proved problematic for these teachers. To this end, the researcher would caution that both pre- and in-service teacher education has a long way to go in order to harness the benefits of grounding the teaching-learning of school science in traditional children's everyday experiences. This once again will require the support of the ministry of education.

Beyond these, for science curriculum innovation efforts to be effective in Sierra Leone, findings from this study would suggest that there must be a change in educational policy in general. Of serious concern is the present weighting on paper qualifications for student placement in jobs, tertiary institutions and for scholarships. Unless this practice is changed, pressure on science teachers to prepare students for examination purposes only will always undermine curriculum innovation efforts aimed at making science education relevant to local needs.

Another policy implication has to do with subject choice for students at the senior secondary school level. The low number of General Science teachers with subject expertise in Physics and Chemistry was identified as one of the major weaknesses of the present junior secondary school science programme in Sierra Leone. The current practice by Sierra Leonean General Science teachers to teach mostly biological science topics at the junior secondary school level has constituted a vicious cycle that goes as follows: Because chemistry and physics components of the General Science syllabus are hardly taught at the junior secondary school level, few students chose to study these subjects when they are made optional at the senior secondary school level. Thus, only a limited number of students will continue to study Physics and Chemistry at tertiary level, which will consequently lead to few science teachers with physics or chemistry background.

In order to break this cycle, the researcher would recommend that the three core sciences - Biology, Chemistry and Physics- should be made compulsory for all science students up to the Fifth Form level. In addition, General Science should be compulsory to non-science students up to the Fifth Form. The current practice of allowing students to drop these subjects after Form 3, but later reintroducing them as course requirements in the tertiary institutions, is self-defeating. Many career discipline training programmes in Sierra Leone like Home Economics, Agriculture, Medicine etc., require backgrounds in the three core sciences of Biology, Chemistry and Physics. Even the pre-service teacher education programmes offer compulsory courses in science.

Alongside the policy changes is the need to review the existing pre-service science teacher education curriculum in Sierra Leone. It is important to note that tertiary teacher education programmes in many African countries were transplanted at the time of political independence without feasibility studies on the appropriateness of these programmes for emerging nations. The secondary school teacher education curriculum at Njala, University college in Sierra Leone, was developed and initiated by personnel from the University of Illinois in America. Despite 30 years of independence, this programme has not been reviewed to address national and local interests. Declarations reported in the present study from teacher educators in that institution about the inappropriateness of the existing pre-service curriculum justify the researcher's concern for a review of the existing programme. Results from the present study showed that Sierra Leonean science teachers were trained and sent to the classroom without developing even the beginning of a philosophy about secondary school science teaching. Such a situation will deter any meaningful curriculum effort, unless the pre-service programme is improved.

In-service training programmes are considered important components of teacher education. It was alarming to learn that the Institute of Education in Sierra Leone did not run regular in-service training courses for secondary school science teachers. Five of the eight participating teachers reported no previous in-service training experience of any kind since becoming teachers (at least 4 years for the most recent teacher). In the light of the inadequate pre-service

preparation of science teachers, the researcher would recommend that regular in-service courses be organised to update serving teachers with recent developments in science education. For economic reasons, such training could concentrate on Heads of Science Departments who could then share their experiences with other science teachers.

9.4 FUTURE RESEARCH

Results of both the case study interviews with science teachers and the students' attitudes to science survey unveiled an unsatisfactory state of science education at the junior secondary school level in Sierra Leone. However, for the purpose of generalisability of these findings, further research involving larger samples of science teachers and students is required.

Many researchers have reported the influence of school and non-school environment on students' attitudes to science. Examples of non-school factors that have been widely investigated include socio-economic status (Fraser, 1980; Malone and Fleming, 1983) and religious background (Lazarowitz and Lazarowitz, 1979; Grose and Simpson, 1982). Relatively, few studies appear to have been conducted on socio-cultural factors - attitudes relationship. In the light of the disparity between traditional African children's thought and life styles and school science, there is need for further investigations to identify aspects of socio-cultural factors that influence science learning at school.

Evaluative statements about the advantages of the new curriculum based on two trial topics only were said to be treated with caution. Thus the desirability of a longitudinal evaluation study of the new curriculum. Such a study should involve more science teachers and should cover all content topics of the new curriculum. Results from a longitudinal study should produce documentation of successes and difficulties experienced by teachers learning about and implementing the new curriculum. The information could be used in subsequent research designed to investigate ways of disseminating ideas of the new curriculum to other science teachers.

The realisation that traditional children hold alternative conceptions about many scientific concepts suggests another direction for future

research. To acquaint science teachers with these conceptions calls for identification of the range of alternative conceptions of different phenomena held by students and their parents. Results from the present study showed that unless teachers are conscious of these misconceptions, they stand to go unaltered since students are shy to put across their alternative views in science lessons. Furthermore, demands to make content of Science for All curriculum intelligible, plausible and fruitful calls for identification of content that fulfil this criterion. Towards this goal, more research is required to investigate aspects of real life situations (indigenous technology and/or traditional common sense explanations of natural phenomena) that could be incorporated in the teaching and learning of school science.

The identification exercise could require deployment of expertise outside the field of education, e.g., specialists from areas of applied science and technology. The task of these 'curriculum writers' would be the delineation of traditional explanations underlying specific indigenous technologies or natural phenomena that could be linked to science education.

To illustrate, Cole and Hamilton (1978) identified a wide variety of indigenous technology uses in Sierra Leone, including:

1. Production, processing and preservation of local food stuff (rice, cassava, pepper).
2. Production of chemicals ('lubi', salt).
3. Native soap making.
4. Palm wine tapping.
5. Production of local gin.
6. Metal work (construction of utensils).
7. Trap making.
8. Preparation of herbal medicines.

The researcher would recommend that future studies in this area should involve curriculum developers in analysing these technologies in order to specify the linked science content for various levels of school

education. This would eventually lead to production of guide books for science teachers to choose from.

Results from the present study did suggest that the idea of grounding the teaching and learning of science in real life situations appeared alien and difficult to implement by the case study teachers. Consequently, there is need for further research in teacher education on ways of improving science teachers' competencies in this area. Such studies should investigate alternative proposals for preparing science teachers which include identification of new roles, skills, and competencies needed by teachers to successfully link science teaching-learning to traditional children's real life experiences. Equally important is the need for further research on ways of instituting these teacher education programmes.

To this end, one useful approach, for example, would be the adoption of a network system at both pre- and inservice levels. The present curriculum dissemination structure of National Curriculum Coordinator ----> Inspectors of Schools ----> Subject Heads of Departments, makes the network approach viable. That is, at the pre-service level for example, the one year post graduate diploma course in Science Education run by Njala University College could be used to provide Inspectors of Schools with a sound theoretical and practical understanding of the new curriculum ideas. On completion of the course, these inspectors would then be responsible for developing and disseminating the new curriculum ideas to Heads of Science Departments in their respective districts. Heads of Departments would in return teach their staff on the use of the new curriculum materials. A similar approach could be used for inservice education.

Finally, one of the major criticisms of the present science programme in Sierra Leone has been the importance attached to public examination which have undue influence on the teaching and learning of science. To minimize this effect, the need for at least partial internal assessment is desirable. Further, in the light of insufficient appropriate instruments, particularly in the affective domain, there is need for further research on alternative ways of assessing students in science. To this end, the Institute of Education should organize workshops for science teachers to provide teachers with skills for the internal evaluation of science learning processes and outcomes.

9.5 CONCLUDING REMARKS

This study evolved out of the researcher's observation that despite 7 to 10 years of formal education, many secondary school dropouts in Sierra Leone display no evidence of having studied any science at school. The standard of living, outlooks to life, and belief patterns about natural phenomena of these dropouts are similar to those held by their communities. Similar concerns have been expressed by researchers from other African countries (e.g., Hoppers, 1980), and many have attributed the cause to the alienating nature of school science (Holmes, 1977; Cole, 1975; Wilson, 1981).

Results from this study would suggest a more fundamental cause of the problem. In the case of Sierra Leone, the system of education show no evidence of preparing students for situations they are bound to find themselves in after schooling. Thus, the present system of education is patterned along examination requirements demanding knowledge and skills that are not relevant to about 80 percent of students who never 'make it' to the University. The situation for science education is worsened further by the inadequate pre-service science teacher education programmes, which do not provide trainees with basic understanding of the philosophy about secondary school science teaching.

In spite of these negative features, a promising finding to emerge from the present study was the science teachers' awareness about the limitations of the existing science programme, and their willingness to participate in innovative curriculum research. This participation produced positive impacts on the teachers' image of school science which, among other things, included recognition of the importance of bridging school science with students' real life experiences. This realisation on the part of the teachers marks an important step towards bringing 'African traditional thought' into school science. Although the two systems have been noted as being radically different on many counts, research evidence suggests that local teachers who understand both the home and school cultures of African children could act as 'cultural brokers' avoiding unmanageable conflict likely to arise (Kileff, 1975). It is these teachers who will have to re-

establish the importance of traditional practices in science education, a process the present system of education has debased.

It must be emphasised, however, that for this merger to be effective in Sierra Leone calls for a change in science education policy. To this end, findings in the present study about teacher and student negative attitudes provide an empirical warrant for change.

Studying science should not be pursued for examination purposes only. Basic knowledge of school science should help traditional children challenge basic problems of their everyday life. For example, knowledge of Biology and Chemistry should help these children understand why running streams are not pure for drinking. The subject matter of school science needs to be changed so that children can really own it in the sense that they can see the meaningfulness of it outside the school in their own socio-cultural background.

APPENDIX 3.1: CONTENT OF THE PROPOSED GENERAL SCIENCE CURRICULUM

BIOLOGY

1. Living and Non-Living Things - Differences between living and non-living things:
 - (a) Features and characteristics of living and non-living things
 - (i) adaptation
 - (ii) interaction
 - (iii) vulnerability (viruses)
 - (b) Clarification of misconceptions about living and non-living things, viz that certain non-living things are innate.
2. Plants and Animals - Differences between plants and animals emphasizing:
 - (a) macroscopic animals - hens, goats, dogs, man, lizard, fish, worms, flies etc.
 - (b) macroscopic plants - mango, rice, grape, pepper etc.
 - (c) qualitative examples of microscopic plants and animals and their economic importance.
3. Study of a Named Flowering Plant
 - (a) Differences between flowering and non-flowering plants.
 - (b) Identification of parts of a flowering plant and their functions.
 - (c) Economic importance of the various parts of a flowering plant.
4. Food
 - (i) Importance of food.
 - (ii) Identification of examples of foodstuffs consumed by different living things (ethical considerations).
 - (iii) Composition, importance of balanced diet, and identification of common diseases caused by malnutrition.
 - (iv) Sources and production of food.

CHEMISTRY

1. WHAT THINGS ARE MADE OF:
 - (a) Description of matter.
 - (b) Different states of matter (qualitative treatment).
 - (c) Classification of matter into simple and complex substances.
 - (d) Definition of substances - elements, compounds and mixtures (emphasising examples of common substances in the environment).
 - (e) Metals and non-metals.
 - (f) Uses and harmful effects of simple substances in the environment.
2. AIR:
 - (a) Composition, uses and importance of air.
 - (b) Determination of wind direction and magnitude and the usefulness of such information in everyday life e.g. weather forecasting - airport traffic controls, forecasting of hurricanes.
 - (c) Air pollution, effects and control.
 - (d) Air borne diseases - types, effects and their control.
3. WATER FOR LIVING:
 - (a) Sources and types of water in the environment.
 - (b) Purification and conservation of water.
 - (c) Uses and harmful effects of water.
 - (d) Identification of water-borne diseases and their prevention.

PHYSICS

1. Units of Measurement:
 - (a) Identification of units of measurements (local and international) for length, mass, volume and time.
 - (b) The metric units and subunits of measurements for length, mass, volume and time.
 - (c) Conversion of metric units of measurement.
2. Density:
 - (a) Real life examples of application of the concept of density.
 - (b) Definition and units of density.
 - (c) Simple experiments and calculations to determine the density of common substances (liquids and solids).
 - (d) Simplified scientific explanations for the application of the concept of density in explaining real life practices: boat making, ship anchorage, separation of liquids and ores etc.

3. Electricity in the Home:

- (a) Sources of electricity: small scale (simple cells) and large scale (generators).
- (b) Identification of common household appliances and their power consumption.
- (c) Safety measures in the uses of electricity at home.

FORM TWO

BIOLOGY

1. Flowers

- (a) Types of flowers in the community.
- (b) Parts and functions of a named common flower.
- (c) Importance of flowers.

2. Fruits and Seeds

- (a) Types of fruits and seeds.
- (b) Classification of common fruits and seeds.
- (c) Preservation of common fruits and seeds.
- (d) Importance of fruits and seeds.

3. Dispersal of Seeds and Fruits and Germination of Seeds

- (a) Description of dispersal & germination.
- (b) Methods of dispersal.
- (c) Importance of dispersal.
- (d) Types of germination.
- (e) Conditions necessary for germination.

4. Vector Animals

- (a) Identification of vectors.
- (b) Features and life cycle of a named vector (one complete and one incomplete).
- (c) Importance of vectors and their control in the community.

CHEMISTRY

1. Mixtures and Compounds

- (a) Properties of mixtures and compounds.
- (b) Composition, uses and chemical formulae of common compounds.
- (c) Separation of mixtures.

2. Solutions

- (a) Components of a solution - solutes and solvents.
- (b) Solubility - definition and factors that affect solubility.
- (c) Uses of solutions.

3. Chemicals in the home

- (a) Physical properties and examples of chemicals in the community.
- (b) Classification and uses of chemicals.
- (c) Effect of chemicals on the environment.
- (d) Safety measures in use of chemicals.

PHYSICS

1. Force

- (a) Scientific meaning of Force.
- (b) Identification of common types of forces and their meaning.
- (c) Qualitative treatment of the uses and effects of some types of forces.

2. Work

- (a) Scientific meaning of work.
- (b) Relationship between force, distance moved and work.
- (c) Clarification of the statement 'No work done'.
- (d) Identification of everyday frameworks of the concept of work (pounding grains, pulling or pushing objects through a distance).

3. Energy

- (a) Qualitative meaning of the term 'Energy'.
- (b) Identification of familiar forms of energy.
- (c) Qualitative explanation of energy transformation.
- (d) Energy conservation: Importance and methods.

APPENDIX 4.1 : A REVIEW OF THEORETICAL BASES OF SOCIAL SCIENCE METHODOLOGIES

In social science studies, the methodological concerns, the kinds of data sought and their mode of treatment are influenced and determined by the viewpoint of the researcher(s) concerned. Differences in viewpoint among researchers stem from different conceptions of reality, and social behaviour. Burrell and Morgan (1979) identify three contrasting sets of assumptions that have direct implications for methodological concerns:

1. Ontological assumptions which concern the very nature or essence of the social phenomena being investigated and poses questions such as: Is social reality external to individuals - imposing itself on their consciousness from without - or is it the product of individuals' consciousness? Is reality of an objective nature, or the result of individual cognition? Is it given 'out there in the world, or is it created by one's own mind?
2. Epistemological assumptions which concern the very basis of knowledge, its nature and forms, how it can be acquired and communicated to other people. Epistemological assumptions can range over extreme positions on the question of whether knowledge is something which can be acquired on the one hand, or is something which has to be personally experienced on the other. How researchers align themselves in this particular debate profoundly affects how they go about uncovering knowledge of social behaviour. For instance, the view that knowledge is hard, objective and tangible, puts researchers in observatory roles with allegiance to the methods of natural science. To see knowledge as personal, subjective, and unique on the other hand, imposes on researchers the involvement with their subjects and rejection of the ways of the natural scientists. To subscribe to the former is to be positivist, to the latter anti-positivist.
3. Assumptions concerning human nature and in particular the relationship between human beings and their environment. Two images of human beings are identified with these assumptions: one that portrays human beings as responding mechanically to their environment, and the other that recognises human as the initiator of their own actions. The distinction between these two perspectives is further amplified by Burrell and Morgan as follows:

Thus, we can identify perspectives in social science which entail a view of human beings responding in a mechanistic or even deterministic fashion to the situations encountered in their external world. This view tends to be one in which human beings and their experiences are regarded as products of the environment; one in which humans are conditioned by their external circumstances. These extreme perspective can be contrasted with one which attributes to human beings a much more creative role: with a perspective where "free will" occupies the centre of the stage; where man is regarded as the creator of his environment, the controller as opposed to the controlled, the master rather than the marionette. In these two extreme views of the

relationship between human beings and their environment, we are identifying a great philosophical debate between the advocates of determinism on the one hand and voluntarism on the other". (SIC).

(Source: Cohen and Manion, 1986, pp.7-8)

Quantitative and Qualitative Research Methodologies

Quantitative Methods

Parallel to these contrasting assumptions have emerged two distinctive methodological perspectives in investigating the social world, positivist or objectivist and anti-positivist or subjectivist approaches.

The positivist approach subscribes to the view which treats the social world as if it were a hard, external and objective reality in which scientific investigation could be directed at analysing the relationships and regularities between selected factors in that world. This perspective expresses itself most forcefully in search of universal laws which explain and govern the reality that is being observed, a process described as being nomothetic. Researchers adopting this approach to study the social world can choose from a range of traditional options - surveys, experiments, and the like. A common feature however, with this approach is the quantitative manner in which studies of the social world are presented.

Recently the predictive feature which underlines most positivistic research techniques in social science have come under severe criticism. Despite the proven success of the technique in scientific enterprise, especially in the field of natural science, its ontological and epistemological bases have been the focus of sustained critique. The technique has been criticised as inappropriate for educational research for a number of reasons which Kirkwood (1988, p.27) summarised as follows.

1. Educational research is within a social community with all the values, beliefs and assumptions shaping the community also shaping the research.

2. Social science and natural science have different purposes.
3. Knowledge is not the objective, value-neutral product of a disinterested observer.
4. Means and ends are inter-related.
5. Theory and observation are inter-related.

Qualitative Research Methods

Out of these dissatisfactions have arisen a variety of schools of thought on anti-positivist research techniques, each with its own subtly different epistemological viewpoint. The influence of the anti-positivist movement has affected constituent areas of social science, particularly those of psychology, social psychology and sociology.

In the field of psychology for instance, a school of humanistic psychology has emerged alongside the co-existing behaviouristic and psychoanalytic schools. In response to the growing feelings of dehumanisation which characterized much of the social and cultural research of the twentieth century, the new school sets to study and understand a person as a whole. On social psychology for example, proponents of science of persons movement contend that because of human beings' self-awareness and powers of language, they must be seen as a system of a different order of complexity from any other existing system whether natural like lower animals, or artificial like computers. Advocates of this school place great importance on the systematic and painstaking analysis of social episodes through a process known as ethogenic method. Unlike positivistic social psychology which ignores or presumes its subjects' interpretation of situations, ethnogenic social psychology concentrates upon the ways in which the subjects construe their social world.

The anti-positivist movement in sociology is represented by three schools of thought - phenomenology, ethnomethodology and symbolic interactionism. A characteristic common to these three schools and one which makes them singularly attractive to educational researchers is the recognition that human subjects are continually adjusting,

reckoning, evaluating, bargaining, acting and changing during social investigations. Hence, researchers belonging to this school of thought argue that the social world can only be understood from the standpoint of the individuals who are part of the ongoing action being investigated. For researchers to understand these behaviours requires sharing the frame of reference of the subjects they investigate, a process described as idiographic. Research techniques grounded in these perspectives are usually qualitative relying heavily on the researchers' senses in interpreting the actions of the subjects.

Kirkwood (1988, p.37) described the following as common characteristics of this type of research:

1. Empirical, since the researcher collects sense data about the phenomena under study.
2. Contextual, since the qualities or entities are studied with the researcher seeking to understand them in a particular context.
3. Sensitive to the environment of the research, since this has a great bearing on how the people think and act.
4. Personal, since the researcher must personally become situated in the subject's environment and reflect the influence it has on the person.
5. Subjective, since the "personhood" of the researcher and the roles and relationships formed between the researcher and subject must be considered.
6. Flexible, since multiple methods are used depending on the situation, and the findings of these alternative methods are compared.
7. Justificationary, since descriptions of methods used are frequently accompanied by justification of the methods chosen, their underlying assumptions, and their limitations.

Reliability and validity are two concerns that make qualitative research vulnerable to criticism from positivistic scholars. However, it is possible to include in qualitative research strategies that can enhance external and internal reliability as well as validity. LeCompte and Goetz (1982) report that one such way of achieving this is by recognising and finding solutions to the following questions:

1. What is the status of the researcher?
2. How are informants chosen?
3. What are the social situations and conditions?
4. What are the analytic constructs and premises?
5. What are the methods of data collection and analysis?

Miles and Huberman (1984) also suggest that internal and external validity of qualitative research can be enhanced by:

1. Checking for representativeness.
2. Checking for research effects.
3. Triangulating.
4. Weighting the evidence.
5. Making contrasts/comparisons.
6. Checking the meaning of outliers.
7. Using extreme cases.
8. Ruling out spurious relations.
9. Replicating findings.
10. Checking out rival explanations.
11. Looking for negative evidence.
12. Getting feedback from informants.

Internal reliability on the other hand is increased by use of low-inference descriptors, multiple researchers, participant researchers, peer examination, and mechanically recorded data collection.

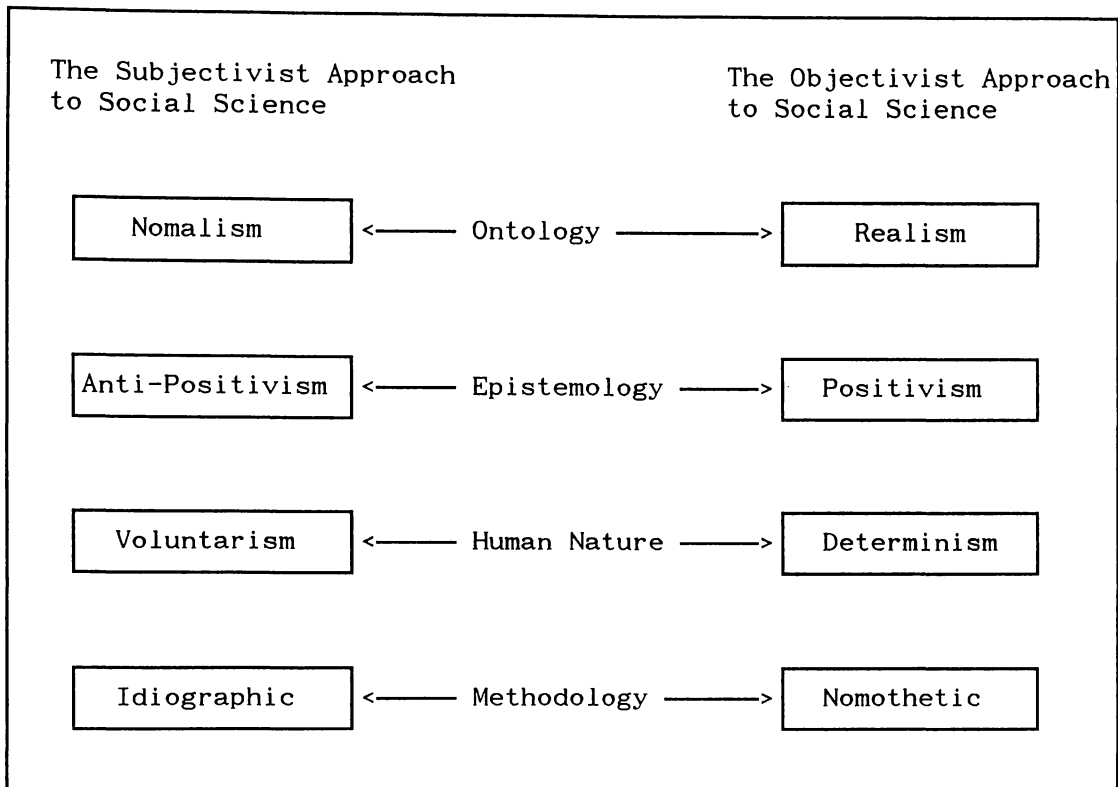
Like the quantitative research techniques, qualitative techniques also have inherent limitations. Miles (1979) describe techniques used in qualitative research as intuitive, primitive, unmanageable and not transcending story telling. The task of social science according to Cohen and Manion (1986) is to develop sets of concepts such as norms, expectations, positions and roles in order to formulate a generalising

science of behaviour. The inability of qualitative techniques to make wide ranging generalisation or to provide objective standards for verifying or refuting theoretical accounts show how short they fall of Cohen and Manion's criterion as tools for investigating social behaviour.

Furthermore, while it is undeniable that one's understanding of the actions of other people requires knowledge of their intentions, this surely cannot be said to compromise the purpose of social science. Critics of qualitative techniques therefore, claim that research based on this approach investigates the meanings and actions of individuals but not the factors engendering or sustaining these meanings. Most importantly, they fail to take account of unintended consequences. Bernstein (1974) also argued that an important factor that must be considered is the power of some people to impose their definitions of situations upon participants. According to him, doctors' consulting rooms and headmasters' studies are examples of locations in which inequalities in power are regularly imposed upon unequal participants. Hence, the ability of certain individuals, groups, classes, and authorities to persuade others to accept their definitions of situations subject idiographic techniques to the same criticisms levied against quantitative techniques i.e. those of presupposing or influencing subjects' responses.

Summary

In summary, the major assumptions underlying the two main extreme categories of research methods (positivistic or quantitative and non-positivistic or qualitative) employed in social science studies are depicted in the diagram below.



Whilst there are social science researchers who adhere to each of the extremes, the assumption of many others are pitched somewhere in the range between the two. In defence of this category of researchers, Reichardt and Cook (1979) note that far from being antagonistic, the two types of research methods are complementary and when used together help to correct the inevitable biases in one another. Further justification for complementary application of the two techniques is provided by Schwartz and Jacobs (1979) who regard qualitative research as a method of scholarly inquiry for gaining a commonsense understanding, whereas quantitative research establishes whether particular phenomena are predictable and controllable.

APPENDIX 4.2: Letter of Introduction of the Researcher for
Principals of Secondary Schools

M

Ministry of Education, Cultural
Affairs and Sports, New England.

SS/550

10th May, 1989.

TO WHOM IT MAY CONCERN

RE: MR. ANDREW A. BAIMBA

I certify that Mr. Andrew A. Baimba (a Sierra Leonean) is a Research Fellow at the Massey University in New Zealand for a period of ten months, and would be grateful for any service you can accord him as a student on Research work.

M. B. Lahai
M. B. Lahai
for: Senior Permanent Secretary



New England,
Freetown.

**APPENDIX 4.3 : Particulars of the Nine Schools included in
the Large Sample Survey on Students'
Attitudes to Science.**

Identification Number	Name of School	Type of School
1	Bo Govt.	Single sex boys
2	St. Andrews	Co-educational
3	Queen of the Rosary	Single sex girls
4	Kenema Govt.	Single sex boys
5	Holy Rosary Kenema	Single sex girls
6	Methodist Kenema	Co-educational
7	Independence Memorial	Co-educational
8	Methodist Boys' High	Single sex boys
9	Annie Walsh	Single sex girls

APPENDIX 4.4 : Résumé of General Science Teachers from Ten Secondary Schools

Name of School	Name of Teacher	Qualification	Subject Speciality
Bo Govt.	John Moriba Marian Murray Albert Yanguba Alfred Kassay Joseph Toko	B.Sc.Ed B.Sc.Ed B.Sc.Ed B.Sc.Ed A Level	Biology Biology Agriculture Agriculture General
St. Andrews	Joseph Gbenjeh Martin Juana Unisa Turay Bashiru Koroma David Ansumana Joseph Sandi	A Level A Level H.T.C. B.Sc. H.T.C. B.Sc.Ed	General General Agriculture Agriculture Biology Agriculture
Gerihun Agric. and Vocational	Paul Tucker	H.T.C.	Biology
Annie Walsh	Dauda Buck Amanda Bangura	B.Sc.Ed B.Sc B.Sc B.Sc.Ed	Agriculture Home Economics Home Economics Chemistry
Methodist Boys Freetown	John Sensie Philip Conteh Nelson Williams Raymond Pratt	H.T.C. B.Sc.Ed B.Sc.Ed Dip. in Eng.	Agriculture Chemistry Physics General
Independence Memorial	Mamie Jusu Amadu Sankoh Kenneth Vandy	H.T.C. H.T.C. H.T.C.	Biology Biology Biology
Methodist-Kenema	Alex Saffa Brima Sama Victor Valcarcell	Certificate 'O' Level H.T.C.	General General Biology
Kenema Govt.	N. Bockarie Moses Tucker	H.T.C. H.T.C.	Agriculture Biology
Holy Rosary Kenema	Rev. Sr. Onwnara M. Smith	H.T.C. H.T.C.	Biology Biology
Queen of Rosary	M. Pawai K. Boima C. Sandy	H.T.C. H.T.C. B.Sc.Ed	Biology Biology Agriculture

APPENDIX 4.5 : ATTITUDES TO SCIENCE QUESTIONNAIRE

1. This exercise contains a number of statements about science. You will be asked what you yourself think about these statements. There are no 'right' or 'wrong' answers. Your opinion is what is wanted.
2. All answers should be given on the separate Answer Sheet. Please DO NOT write on the question booklets.
3. For each statement, draw a circle around
 - SA if you **STRONGLY AGREE** with the statement:
 - A if you **AGREE** with the statement:
 - N if you are **NOT SURE**:
 - D if you **DISAGREE** with the statement:
 - SD if you **STRONGLY DISAGREE** with the statement.

Practice Item

It would be interesting to learn about boats.

Suppose that you **AGREE** with this statement but do not **STRONGLY AGREE** with the idea of learning about boats, then you would circle **A** on your Answer Sheet like this:

SA A N D SD

- 4 If you change your mind about an answer, cross it out and circle another one. But make sure that there is only one answer to every question.
- 5 Answer **ALL QUESTIONS**.
- 6 You can ask for **HELP** on any statement you find difficult to understand.

1. I find topics covered in science useful in my everyday life.
2. Anything we need to know can be found out through science.
3. I would rather find out something for myself than have someone tell me.
4. I do not mind reading about things which disagree with my previous ideas.
5. Science lessons are fun.
6. I would like to be a member of the science club.
7. I would dislike being a scientist after I leave school.
8. I dislike science because it is full of topics that are unfamiliar to me.
9. Scientists cannot always find answers to their questions.
10. Doing experiments is not as good as getting the answer from teachers.
11. I dislike doing the same experiments over and over to make sure I get the same result.
12. I dislike science lessons.
13. I get bored with watching science films or movies.
14. When I leave school, I would like to work with people who make discoveries in science.
15. I would like to study science even though I don't want to become a scientist.
16. Scientific knowledge is unchanging.
17. I would rather do experiments than read about them in books.
18. I am interested to know about the world in which we live.
19. School should have more science lessons each week.
20. I would like to be given a science book or some scientific equipment like a microscope as a present.

PLEASE TURN OVER

21. I would dislike a job in a science laboratory after I complete school.
22. Only educated people can benefit from the type of science we learn at school.
23. The main ideas in science will never need to be changed.
24. I would prefer to believe what other people tell me than do an experiment to find out for myself.
25. Finding out about new things is unimportant.
26. Science lessons bore me.
27. I dislike reading books about science during my holidays.
28. Working in a science laboratory would be a nice way of earning money.
29. I like science because it teaches about practical things I come across in everyday life.
30. Scientific laws cannot be changed.
31. I would prefer to do my own experiments than to find out the answer from a teacher.
32. I like to listen to people whose ideas are different from mine.
33. Science is one of the most interesting school subjects.
34. I would like to do science experiments at home.
35. An occupation in science would be dull and boring.
36. I dislike science because it is not useful in my everyday life.
37. Scientists are always willing to change their ideas.
38. I would rather find out about things by asking someone who knows the answers than finding out for myself.
39. I find it boring to hear about new ideas.
40. Science lessons are a waste of time.

PLEASE TURN OVER

41. Talking to friends about science after school would be boring.
42. I would like to teach science when I complete school.
43. The examples used in science lessons are things I come across in everyday life.
44. Physics is an exact science because physicists are able to make measurements without error.
45. I would rather solve a problem by doing an experiment than be told the answer.
46. In science experiments, I like to use new methods which I have not used before.
47. I really enjoy going to science lessons.
48. I would enjoy working in a science laboratory in the holidays.
49. A job as a scientist would be boring.
50. The only reason I study science is to pass my examinations.
51. Some questions cannot be answered by science.
52. It is better to ask the teacher the answer than to find it out by doing experiments.
53. I am unwilling to change my ideas when evidence shows that the ideas are poor.
54. The topics covered in science lessons is uninteresting.
55. Listening to talk about science on the radio would be boring.
56. An occupation as a scientist would be interesting.
57. The science I learn at school can be used to solve problems in my community.
58. We can always get answers to our questions by asking scientists.
59. I would prefer to do an experiment on a topic than to read about it in science books.
60. In science experiments, one should record all the results, not just the expected answers.

PLEASE TURN OVER

61. I look forward to science lessons.
62. I would enjoy visiting a science museum on weekends.
63. I would dislike becoming a scientist because it needs too much education.
64. The science I learn at school is only important for those who would like to become scientists.
65. One of the most important jobs of scientists is to report exactly what they observe.
66. It is better to be told about science than find it out from experiments.
67. I dislike listening to other people's ideas.
68. I would enjoy school more if there were no science lessons.
69. I dislike reading about science in newspapers.
70. I would like to be a scientist when I complete school.

THE END

APPENDIX 4.6: Attitudes to Science Questionnaire Answer Sheet

Name _____

School _____ Year/Form _____

Page 2						Page 3						Page 4					
	STRONGLY AGREE	AGREE	NOT SURE	DISAGREE	STRONGLY DISAGREE		STRONGLY AGREE	AGREE	NOT SURE	DISAGREE	STRONGLY DISAGREE		STRONGLY AGREE	AGREE	NOT SURE	DISAGREE	STRONGLY DISAGREE
1	SA	A	N	D	SD	29	SA	A	N	D	SD	50	SA	A	N	D	SD
2	SA	A	N	D	SD	30	SA	A	N	D	SD	51	SA	A	N	D	SD
3	SA	A	N	D	SD	31	SA	A	N	D	SD	52	SA	A	N	D	SD
4	SA	A	N	D	SD	32	SA	A	N	D	SD	53	SA	A	N	D	SD
5	SA	A	N	D	SD	33	SA	A	N	D	SD	54	SA	A	N	D	SD
6	SA	A	N	D	SD	34	SA	A	N	D	SD	55	SA	A	N	D	SD
7	SA	A	N	D	SD	35	SA	A	N	D	SD	56	SA	A	N	D	SD
8	SA	A	N	D	SD	36	SA	A	N	D	SD	57	SA	A	N	D	SD
9	SA	A	N	D	SD	37	SA	A	N	D	SD	58	SA	A	N	D	SD
10	SA	A	N	D	SD	38	SA	A	N	D	SD	59	SA	A	N	D	SD
11	SA	A	N	D	SD	39	SA	A	N	D	SD	60	SA	A	N	D	SD
12	SA	A	N	D	SD	40	SA	A	N	D	SD	61	SA	A	N	D	SD
13	SA	A	N	D	SD	41	SA	A	N	D	SD	62	SA	A	N	D	SD
14	SA	A	N	D	SD	42	SA	A	N	D	SD	63	SA	A	N	D	SD
15	SA	A	N	D	SD	43	SA	A	N	D	SD	64	SA	A	N	D	SD
16	SA	A	N	D	SD	44	SA	A	N	D	SD	65	SA	A	N	D	SD
17	SA	A	N	D	SD	45	SA	A	N	D	SD	66	SA	A	N	D	SD
18	SA	A	N	D	SD	46	SA	A	N	D	SD	67	SA	A	N	D	SD
19	SA	A	N	D	SD	47	SA	A	N	D	SD	68	SA	A	N	D	SD
20	SA	A	N	D	SD	48	SA	A	N	D	SD	69	SA	A	N	D	SD
21	SA	A	N	D	SD	49	SA	A	N	D	SD	70	SA	A	N	D	SD
22	SA	A	N	D	SD	For Teacher Use Only S ____ N ____ I ____ A ____ E ____ L ____ C ____											
23	SA	A	N	D	SD												
24	SA	A	N	D	SD												
25	SA	A	N	D	SD												
26	SA	A	N	D	SD												
27	SA	A	N	D	SD												
28	SA	A	N	D	SD												

APPENDIX 4.7 : Table of communalities, eigen values, and percentage variance associated with each factor extracted.

Variable	Communality	Factor	Eigen Value	Percentage of Variance	Cummulative percentage
C1	0.30	1	6.54	9.4	9.4
C2	0.22	2	3.51	5.0	14.4
C3	0.12	3	2.14	3.1	17.4
C4	0.19	4	1.88	2.7	20.1
C5	0.18	5	1.58	2.3	22.4
C6	0.35	6	1.54	2.2	24.6
C7	0.27	7	1.48	2.1	26.7

CORRELATION OF ITEMS WITH FACTORS THAT THEY LOAD ON

Variable	Corresponding Science & related attitudes scales	Range of correlation
C1	4	0.44
C50	1	0.36
C36	1	0.34
C19	5	0.33
C64	1	0.31
C58	2	0.31
C2	2	0.29
C8	1	0.24
C15	1	0.195
C70	7	0.72
C40	7	0.64
C47	5	0.60
C61	5	0.59
C48	6	0.59
C62	6	0.51
C56	7	0.47
C33	5	0.43
C34	6	0.42
C14	7	0.36
C26	6	-0.33
C28	7	0.29
C43	1	0.29
C63	7	-0.28

Variable	Corresponding Science & related attitudes scales	Range of correlation
C65 C7 C51 C21 C46 C60	2 7 2 7 4 4 none	-0.50 -0.32 -0.31 -0.29 -0.27 -0.21
C41 C49 C55 C26 C35 C39 C12 C5 C13 C54 C67 C69 C9 C40 C25 C68	6 7 6 5 7 4 5 5 6 5 4 6 2 5 4 5 5 6 5	-0.60 -0.53 -0.51 -0.49 -0.48 -0.43 -0.41 -0.40 -0.40 -0.36 -0.35 -0.34 -0.31 -0.31 -0.28 -0.23
C18 C1 C29 C20 C6 C32 C44 C57	4 1 1 6 6 4 2 1 none	0.59 0.53 0.51 0.46 0.43 0.36 0.29 0.26
C52 C31 C38 C59 C24 C66 C17 C10 C45	3 3 3 3 3 3 3 3 3 3	0.62 -0.54 0.47 -0.42 0.40 0.38 -0.33 0.33 -0.31
C23 C30 C37 C22 C11 C3 C53 C16	2 2 2 1 4 3 4 2 2	-0.62 -0.58 0.35 -0.35 -0.28 -0.26 -0.20 -0.15

APPENDIX 4.8 : Teachers' Self Evaluation Questionnaire

Title of Unit

Have you taught the topic in this unit before?

If yes, what approach have you been employing in teaching this topic?
.....
.....
.....

Do you think the instructional guide enhanced your teaching of the
topic this time?

If yes, how?

.....
.....
.....
.....

If any, list some of the advantages of the instructional guide

.....
.....
.....
.....

Is the material covered in the package adequate for the level of
the pupils?

.....
.....
.....

What material(s) would you want added or removed from the package
.....
.....
.....
.....

How many 40 (minutes) periods did you use to complete the unit?
.....

Did the pupils have prior ideas about the topic covered in this
unit?

.....
.....

List some of the ideas (misconceptions) pupils had about the topic.

.....
.....
.....
.....

Did you identify any norms that inhibit the development of the concept?

Give examples

How did the pupils respond to this alternative approach of teaching science?

.....
.....
.....

Do you think that the proposed approach will positively influence the pupils' attitudes to science?

Give reasons for your answer

Give examples of real life applications of the concept as identified by the pupils

.....
.....
.....
.....

Did you employ any community resource(s) in teaching this unit?

.....

Explain

APPENDIX 4.9 : SUMMARY OF INSERVICE TRAINING

Report on the inservice training of science teachers in Sierra Leone

(Written by Tamba Ngawuja)

Topic discussed: The development of Science for All
curriculum in non-Western societies

Participants:

		<u>Subject Speciality</u>	<u>School</u>
Group A	S.T. Ngawuja	- Physics	- Bo School
	J.P. Moriba	- Biology	- Bo School
	S.M. Navo	- Biology	- St. Andrews
	A.J. Yanguba	- Agriculture	- Bo School
	U.F. Turay	- Agriculture	- St. Andrews
Group B	J. Sandy	- Biology	- Cerihum
	J.C. Sandi	- Agriculture	- St. Andrews
	B.M. Koroma (observer)	- Agriculture	- St. Andrews
	P. Tucker	- Biology	- Cerihum

Working Papers

1. The Secondary School General Science Curriculum in Sierra Leone: State of Art (The Teachers Perspective).
2. Role of Science Education in Developing Countries.
3. The Scientific Knowledge/Cultural Interface.
4. School Science Pedagogy: Present Practices in Sierra Leone, Advantages and Limitations.
5. The Dilemma of Relevance in Science Education and Guidelines for Determining Aims and Objectives of Meaningful General Science Curriculum in Developing Nations.
6. The Psychological Basis i.e. The Constructivist View of Learning Science and Learning As a Conceptual Change.

Method used in the inservice training and the results thereof

There were nine science teachers from different disciplines involved.

For discussion purposes, teachers were separated into two groups (refer Groups A and B above).

Working papers were presented, and at the end of each paper the two groups would discuss the contents in separate groups.

Different views were put forward about the relevance or otherwise of science curriculum to the local environment, and suggestions were made for improvement.

At the conclusion of the training, discussion was held on the following various learning and teaching strategies to guide teachers in the development of trial teaching materials from the new curriculum. :

First working paper: Title: Secondary School General Science Curriculum in Sierra Leone: State of the art (the teacher's perspective). Following is a precis of the paper.

The lack of a national general science curriculum in Sierra Leone was highlighted. The present practice is for Heads of Departments with other science teachers in their respective schools to draw up topics for the teaching of general science. The factors taken into consideration when drawing up these topics are:

- (i) availability of textbooks.
- (ii) the West African Examinations Council (W.A.E.C.) syllabus.

General science is composed of physics - chemistry - biology and are taught terminally in these schools. Some of the aims and objectives of general science in lower secondary schools as supplied by various heads of science departments and teachers were:

- To teach pupils the basic definition of physics, chemistry and biology.
- To prepare pupils for further studies in the sciences.
- To familiarize pupils with science equipments.
- To introduce the basic concept of science to the pupils.
- To help the majority who will not become scientists appreciate the technological world.

Topics in General Science were taught to satisfy the need for preparing pupils for the W.A.E.C. 'O' level examinations. The present science syllabus is not relevant to those who do not go beyond the middle school. The teaching methods are didactic.

The poor working conditions inhibit teachers' commitment to the job. The teacher employs the easiest methods to impart scientific knowledge (chalk & talk). This forces pupils to resort to memorization of notes. Little or no relationship is made between the content and the pupils environment. Teachers are also under pressure to teach the given scheme for that term if they are not to be reprimanded. Too many topics for few periods. Furthermore, short periods and large classes inhibit activity oriented teaching.

The calibre of teachers is also an inhibiting factor. Physics and chemistry teachers are restricted to the upper schools to prepare pupils for the 'O' level and 'A' level examinations and therefore agricultural bias and 'A' level pupils are deployed to teach general science in the lower school. At times little or no physics and chemistry is taught in the lower school general science course. This negates the pupils attitude towards physics and chemistry.

Tertiary institutions on the other hand are not preparing teachers capable of teaching general science as an integrated course comprising physics, chemistry and biology.

The content of general science is presented to the pupils as something alien. Teachers make no allowances for relating what they teach, to the pupils' own perception of the concept taught.

The present practice can be conceived as one of indoctrination. It is akin to the traditional outlook for the acquisition of knowledge.

During the discussion that followed, the group agreed that the present general science is not useful to the majority of the pupils. However the practice cannot be easily changed because of the norms set by the administrators.

The group also observed that the teacher's own experience and the community he lives in restricts his choice of examples when teaching. He uses more urban rather than rural examples which result in alienating a portion of the class - a flaw in the present teaching method.

Furthermore, the teacher is concerned about teaching the pupils to pass the 'O' level examination, hence his choice of examples and illustrations is dictated by the W.A.E.C. syllabus. Local examples are not encouraged.

Presentation of second working paper: Title: Role of Science Education in Developing Countries. A precis follows:

Education must not only be the acquisition of inert ideas, but the knowledge must also be useful in the learner's life.

It is a fact the science dominates the school curriculum. However the question arises: Does school science provide useful knowledge to majority of the learners in developing countries? Hence a need for restructuring the curricula in developing countries.

Science education should not alienate the learner from his cultural practices and values, but must be adapted to the cultural practices and values of the learner and also be closely related to real life situations. Since developing countries are characterized by authoritative and close thinking styles, science must be used for sharpening the skills and curiosity of the children - developing critical thinking and the use of scientific method in solving their problems.

Science and its applications when adapted responsibly and with due recognition of the cultures of various societies should have much to contribute to the:

- (i) economic and natural development of the individual's society.
- (ii) maintenance and restructuring of nature.
- (iii) aesthetic development of the individual.

For indigenous development, science must not be restricted to the few cadre but must cover a broader perspective. Directing science to a greater population has advantages such as:

- (i) provides a wide talent base from which technicians and skilled craftsmen can be drawn.
- (ii) making it easier for society to accept meaningful improvements and innovations.
- (iii) involving society in the making of decisions that involve technical changes and be able to relate such changes to their own cultural values.

- (iv) helping to meet the material needs of its populace.

'Science for all' is therefore advocated. It should be a science that provides scientific competence, knowledge and skills for individuals that would help eradicate poverty, provide decent living conditions, work, and the achievement of social justice. The context of science for all ought to be an extension of what the learners already know from their experiences prior to schooling - its aims and objectives must embrace criteria for development. The learning of practical and cognitive skills must not be the focus of learning but must flow naturally from the scientific topics taught. Positive experiences must evolve from pupils' encounters with science, hence a need for the development of an indigenous or culturally based science curricula programme.

The goals of 'Science for all' can be optimized by exploiting the potentials of local indigenous technologies for teaching science content - using cultural elements and belief, and linking what is familiar in the pupils' environment to the more sophisticated scientific concept - an issue based approach.

At the end of the presentation, the papers are discussed and the following questions are raised for group discussion.

Questions

1. What are the advantages and disadvantages of restricting physics and chemistry specialist teachers to the senior secondary school level?
2. What changes might take place if specialised teachers teach general science?
3. How appropriate is the current science curriculum for national development?
4. What are the aim of general science curriculum?

Responses to these questions by the two groups can be found in the following section.

Specialized teachers might have their advantages, but the question of their teaching general science instead of their specialized areas will not be effective. Specialized teachers from different areas teaching general science may find it difficult to relate certain concepts to the pupils' environment because of their own handicap. Towards this, the need for the training of teachers to teach general science was brought up. The use of workshop and inservice courses will help in the preparation of such teachers i.e. teachers specialized for the teaching of general science since the tertiary institutions in Sierra Leone were not doing.

The question of the Head of Science Department/teacher's ability to draw up a general science syllabus was discussed. The teacher might be qualified, but the group pointed out that there is a tendency for the head/teacher to choose only topics that he/she is familiar with.

The group pointed out that the teachers must have a clear understanding of the philosophy of science education. They suggest that instead of a single teacher drawing up a syllabus, teachers from

different regions should undertake such a task. Such a group will take into consideration the different specialized areas of physics, chemistry and biology and also the cultural background of the learners.

Members of the group see the difficulty in the complete integration of physics, chemistry and biology. Instead they suggest that integrable areas should be identified, which can contribute to a new general science syllabus. To enhance effective teaching, availability of new textbooks is essential.

The group observed that to make general science functional, the stress on the preparation of pupils for public examinations should be minimized. Instead an alternative means of assessing the pupils should be looked at. For it to be functional the learner should be able to relate scientific concepts to his/her environment and help towards solving environmental problems.

Members point out that not all topics in science are relevant to the pupils' environment. Topics that can be integrated should be taught in the junior forms, with specialized areas for senior forms. Instead of changing the syllabus, the group suggests that we extend the present syllabus by relating the content to other areas.

On that basis, it was agreed that the present school syllabus is not the issue at stake but the teachers' interpretation of the syllabus.

Presentation of the third working paper: Title: The scientific knowledge/cultural interface: Implications for science education.
Summary of this paper is shown below.

Certain writers believe that scientific education in developing countries alienate the learners from their culture, frustrates them, and renders them useless to their communities. The reason advanced for this is the disparity between Western science education and traditional practices. In comparing a Western and traditional Africans, the Western person is portrayed as self centred. Learning to him means forging ahead. The African on the other hand, is seen as living with and for his tradition, and learning means practicing tradition. Similarly, whereas the Western child is seen as being brought up to be independent and curious, the African child is taught to be submissive, accept circumstances, and for him education is an informal process i.e. by the initiation of elders.

This disparity between the Western and traditional African children's outlook is an important factor that must be considered when designing a science curriculum for our situation. It must be remembered that the aims and objectives of education for the traditional African man inhibits innovations and conforms the pragmatist to the norms of society which stifles development.

Consequences of the disparity in science education is highlighted.

The fourth and sixth working papers were combined and presented as a single paper.

Fourth working paper: Title: School science pedagogy: Present practices in Sierra Leone, advantages and limitations.

Sixth working paper: Title The psychological basis i.e. the constructivist view of learning and learning as a conceptual change. A precis follows:

The discovery method of teaching science was mentioned. Its disadvantage however is the assumption that the learner is a neutral observer who lacks a pre-knowledge about situations.

These earlier ideas have now been challenged by the constructivist view which infers that learners have already developed concepts about their world before entering a learning situation. That they have developed mini theories which can be accepted, changed or rectified during the learning process.

The three areas of science, lay, gut and school science are discussed. Notwithstanding the difficulty of relating gut and lay science to school science, it is pointed out that using the lay and gut science of learners in the teaching of science in the junior schools should provide a more meaningful place for the formalized science taught in the senior schools.

According to the conceptual change model, learning can be acquired by

- (i) the addition of new concepts to existing structures;
- (ii) modifying existing structures;
- (iii) restructuring of existing structures.

Underlying this conceptual change model are arguments that knowledge is a relative phenomenon, not an absolute one.

Individuals are seen as a participant in the learning process, and not observers.

Learning must depend on the learners' initial knowledge.

The papers were discussed and questions for group discussion posed. These were:

Questions:

1. From your experience, what are the effects of traditional norms on the teaching-learning of general science?
2. How important is laboratory experimentation in the teaching-learning of general science at the junior secondary school level?
3. How feasible is learning by conceptual change in the Sierra Leone context?
4. Should general science curricula be centrally or locally controlled?

Summary of group discussions are presented below:

Conflict arises between the pupils' acquired scientific explanations to concepts and the traditional explanation of similar concepts. In resolving this conflict the society plays a significant role. For

example, the traditional misconception about echoes and its effect on the teaching of that concept was mentioned.

Another example was traditional belief about the chameleon and how it inhibits students learning about that animal.

It was noted too that teachers' personal belief can restrict them from teaching certain topics effectively. Hence the need for teachers re-education to dispel some of these misconceptions was stressed.

The negative impact of the pupils' environment on their learning of science was discussed. Examples relating to health, agriculture, natural phenomena whose traditional explanations were in conflict with scientific explanations were lengthy discourses. In short, teachers believed that traditional norms do affect the teaching of general science.

Further discussion pinpointed situations in which simple experimentation can be used to resolve the conflict between traditional and scientific explanations for some concepts. As a consensus, the group believed that experimentation can be used simultaneously with the lay and gut sciences of the pupils in order to circumvent these stumbling blocks. It is a useful means by which pupils can test their ideas and draw inferences. Experimentation then remains a useful method for the effective teaching of functional science.

Various instances were cited in which learners with mini theories or concepts try to experiment to either disprove or support them. By the use of interviews the pupil's initial knowledge of a concept can be identified.

Teachers agreed that pupils have their own interpretation of certain natural phenomena and these interpretations vary from region to region. Pupils therefore already have set explanations to the concepts involved in these phenomena. These set theories can be used as starting points to teach these concepts. The method of conceptual change can therefore be employed in these situations to teach the concepts.

Since the explanations to traditional phenomena and norms vary between regions, the group suggested that a regional based rather than a national based curriculum will enhance effective teaching of meaningful science.

Presentation of the fifth working paper: Title: The dilemma of relevance in Science Education and guidelines for determining aims and objectives of meaningful general science curriculum in developing nations". Below is a precis:

Aim of general science should be: to make the learner independent and to produce technological advancement. Parents see education as a means of improving the social status of their children. Thus, the subjects of physics, chemistry and mathematics are seen as subjects for the elite, while subjects like agriculture, woodwork, home-economics etc. are perceived as inferior and hence looked down upon by society.

Science education should call for more than what 'Science for All' stands for. The intellectual development of science should not be

overlooked while we are advocating 'Science for All'. The different attitudes and aspirations of pupils must also be considered. Due to the need for intellectual development and the need for 'Science for All', the question of separate curricula to cater for the two groups was raised as an issue for discussion.

The advantages of culturally linked curriculum was emphasized. It brings the learner closer to their environment and make science more meaningful and appreciated. It renders science more applicable and relevant to traditional and technological advancement. It also attempts to resolve conflicts between traditional and scientific outlooks towards nature.

The flaws of the present school science was highlighted viz. the most essential topics relevant to useful learning are hardly taught in junior science classes.

Suggestions to guide determination of meaningful aims and objectives of science curricula were given, including:

- (a) development of a positive attitude to science.
- (b) preparing the learner both intellectually and behaviourally to face real life situations.
- (c) to understand science, the context under which its content is taught is important. The content should be related to the community. It should be geared towards solving and developing traditional technology.

The paper is discussed and the following pertinent questions were raised that were to be discussed by the two groups separately and their responses presented in a report the next day.

1. What is relevant science curriculum?
2. Do we advocate for two types of curricula: one for the Science for All and the other for students with career interest in science?

Presentation of the groups' report on the fifth working paper was discussed. A summary of the discussion follows:

The important role teachers can play in determining what is relevant in education was emphasized. Failure to consult them can lead to the development of a curriculum that is irrelevant to both economic and social development. It is pointed out that teachers are not adequately consulted by the government in matters relating to curriculum changes.

The group agreed that an aim of education in Sierra Leone must be to develop the intellect of the individual, and assist him to develop skills that will make him independent and contribute to the state's development. However, it was observed that the fact that the state determines to a large extent what is relevant in education has an adverse effect on the type of education provided for the learner. Such an education most times leads to low productivity and unemployment, which renders it useless to society. The use of teachers to interpret the government's educational policies, will help identify its flaws which can be prevented or corrected by the teachers during implementation. The group arrived at the conclusion that emphasis should be placed on the learner to determine what is relevant

in education. After all the learner in the end will be applying what is learnt to develop his/her life.

The attitude of the community to education which can act as a reinforcer for the learner is a factor that should be considered when determining the aims of education. The outlook of the community to education e.g. the grammar school type of education is what the community focuses on rather than vocational education. These are seen as inferior vocations or jobs - carpentry, bricklaying etc. To make science education meaningful for the pupils, the attitude of the community needs to be changed. Any approach adopted must be geared towards improving the community practices and introducing new ideas that will dispel the community's misconceptions. Convince the community that science education is functional and hence can be used to improve community life. The group observed that the aims of colonial education i.e. to fill clerical jobs are still has great influence over the school curriculum and this should be rectified.

After discussing the pros and cons for the following options: (1) A separate syllabus for the lower and upper schools, (2) using the syllabus as it stands, (3) to simply make an extension or modification of the present syllabus such that the lower school science becomes functional and at the same time provide the necessary attitudes and skills necessary to foster future learning of science; the following points support the third option: The acute shortage of science teachers could not permit the use of two types of science curricula.

The group advocates that we use topic-centred structure that relates the concepts to real life applications. It was observed that such a modification will require limited inservice courses for training teachers to acquire the skills needed to teach such curriculum.

The talk on various learning and teaching strategies is summarised in the following section.

Learning should be related to the learner's own experience.

These experiences should be chosen as key elements in helping students to have enjoyable, stimulating and successful learning environments.

It is a tool which can help teachers to be inventive.

The pupils need to understand the purpose of the learning activity, which should be set in an environment that is relevant to the pupils' lives.

The use of different learning strategies improves the learning process.

Some examples of various learning processes are: Brainstorming, investigation, drama, displays, games, interviews, demonstrations and projects etc.

The teaching strategy employed at any one time will depend on the topic taught and the circumstances under which it is taught.

The teacher must provide opportunities for pupils to engage in problem solving activities that are open ended. Relate pupils' ideas to science as far as possible.

Pupils need to test out ideas, construct new ideas, to share ideas. Or the curriculum needs to reflect the above ideas also provide opportunities to help them satisfy these needs.

The use of the conceptual change model to help make science more meaningful are emphasized. It helps pupils relate what they already know to newly introduced ideas.

Pupils should be involved in investigations outside the classrooms and use such opportunities to clarify their misconception. Rapport between teacher and pupils should be encouraged.

Teaching strategies:

The teacher needs the skills to coordinate and facilitate children's learning, to respond to group and individual needs by promoting an effective learning environment.

The teacher leads and organizes the pupils such that they are actively involved in the learning process, and does not act as a source house of knowledge but should take into consideration the pupils' needs.

A teacher's role is to promote an effective learning environment.

The aim of brainstorming is to record and accept the pupils' ideas on the topics and issues in question. It provides a focus for discussion and encourages the range of the ideas in the classroom.

These ideas can be collected earlier by writing all the responses on the board, using small discussion groups to discuss these concepts and the teacher to record the results of these discussions etc.

Learning must not be viewed as an addition of new ideas to what the pupils already know but as a modification of what they already know.

In summary, the following points were emphasised as important teaching strategies.

1. use stimulating starter activities.
2. help students to clarify their own ideas.
3. help students to modify their ideas.
4. help students accept and use with confidence their new ideas.
5. help students study how to learn.
6. encourage pupils to take full responsibility for their own learning.
7. create a friendly supportive learning environment that encourages pupils to discuss, express, share and test their ideas.
8. listen to students and understand their ideas, experience, interest, and accept their ideas.
9. encourage students to initiate their own ideas.
10. ensure that pupils communicate their ideas through graphs, charts and maps.
11. be willing to be learners as well.

APPENDIX 4.10: Raw data large sample attitude survey

Title "Programme segment for reading data"

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(f4.0,71(f1.0))

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compute c72 =30 -c2+ c9- c16- c23-c30+c37- c44+ c51- c58+ c65

compute c73 =30 + c3-c10+ c17-c24+ c31- c38+ c45- c52+ c59- c66

compute c74 =30 + c4-c11+ c18-c25+ c32- c39+ c46- c53+ c60-c67

compute c75 =30 + c5- c12+ c19- c26+ c33- c40+ c47- c54+ c61- c68

compute c76 =30 + c6- c13+ c20- c27+ c34- c41+ c48- c55+ c62- c69

compute c77 =30 -c7+ c14- c21+ c28- c35+ c42- c49+ c56- c63+ c70

variable labels c71 'Application of sc. kn.'

/ c72 'understanding of natutre of science'

/c73 'Attitude to. Inquiry' /c74 'Adoption of scientific att'

/c75 'Enjoyment of science lessons' /c76 'Leisure interest in science'

/c77 'Career interest in science'

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(502 thru 567=7) (568 thru 608=8) (609 thru 642=9)

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APPENDIX 4.11 Raw data: pre-survey Bo and St. Andrews Schools

Bo Pre-Survey

Title "Programme segment for reading data"

data list fixed file='thesis.dat' records=1 / subno c1 to c70 gender
(f4.0,71(f1.0))

recode c1 to c70 (missing=3)

compute c71 =30 + c1 - c8 + c15 - c22 + c29 - c36 + c43 - c50 + c57- c64

compute c72 =30 -c2+ c9- c16- c23-c30+c37- c44+ c51- c58+ c65

compute c73 =30 + c3-c10+ c17-c24+ c31- c38+ c45- c52+ c59- c66

compute c74 =30 + c4-c11+ c18-c25+ c32- c39+ c46- c53+ c60-c67

compute c75 =30 + c5- c12+ c19- c26+ c33- c40+ c47- c54+ c61- c68

compute c76 =30 + c6- c13+ c20- c27+ c34- c41+ c48- c55+ c62- c69

compute c77 =30 -c7+ c14- c21+ c28- c35+ c42- c49+ c56- c63+ c70

variable labels c71 'Application of sc. kn.'

/ c72 'understanding of nature of science'

/c73 'Attitude to scientific enquiry' /c74 'Adoption of scientific att'

/c75 'Enjoyment of science lessons' /c76 'Leisure interest in science'

/c77 'Career interest in science'

Recode subno (1 thru 157=1) (158 thru 315=2) (316 thru 358=3)

(359 thru 397=4) (398 thru 431=5) (432 thru 501=6)

(502 thru 567=7) (568 thru 608=8) (609 thru 642=9)

(643 thru 781=1) (782 thru 931=2) (932 thru 972=3)

(973 thru 1022=4) (1023 thru 1060=5) (1061 thru 1112=6)

(1113 thru 1171=7) (1172 thru 1212=8) (1213 thru 1247=9)

(1248 thru 1370=1) into school/

subno (1 thru 157=1) (158 thru 315=3) (316 thru 358=2)

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into streams

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Appendix 4.12 Raw data: Post survey Bo and St. Andrews schools

Bo Post-Survey

```
Title "Programme segment for reading data"
data list fixed file='newnos.dat' records=1 / nstreams oldno c1 to c70
  pro subno (f1.0,f4.0,71(f1.0),f4.0)
recode c1 to c70 (missing=3)
compute c71 =30 + c1 - c8 + c15 - c22 + c29 - c36 + c43 - c50 + c57- c64
compute c72 =30 -c2+ c9- c16- c23-c30+c37- c44+ c51- c58+ c65
compute c73 =30 + c3-c10+ c17-c24+ c31- c38+ c45- c52+ c59- c66
compute c74 =30 + c4-c11+ c18-c25+ c32- c39+ c46- c53+ c60-c67
compute c75 =30 + c5- c12+ c19- c26+ c33- c40+ c47- c54+ c61- c68
compute c76 =30 + c6- c13+ c20- c27+ c34- c41+ c48- c55+ c62- c69
compute c77 =30 -c7+ c14- c21+ c28- c35+ c42- c49+ c56- c63+ c70
variable labels c71 'Application of sc. kn.'
/ c72 'understanding of natutre of science'
/c73 'Attitude to scientific enquiry' /c74 'Adoption of scientific att'
/c75 'Enjoyment of science lessons' /c76 'Leisure interest in science'
/c77 'Career interest in science'
Recode subno (1 thru 157=1) (158 thru 315=2) (316 thru 358=3)
  (359 thru 397=4) (398 thru 431=5) (432 thru 501=6)
  (502 thru 567=7) (568 thru 608=8) (609 thru 642=9)
  (643 thru 781=1) (782 thru 931=2) (932 thru 972=3)
  (973 thru 1022=4) (1023 thru 1060=5) (1061 thru 1112=6)
  (1113 thru 1171=7) (1172 thru 1212=8) (1213 thru 1247=9)
  (1248 thru 1370=1) into school/
  subno (1 thru 157=1) (158 thru 315=3) (316 thru 358=2)
  (359 thru 397=1) (398 thru 431=2) (432 thru 501=3)
  (502 thru 567=3) (568 thru 608=1) (609 thru 642=2)
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  (1113 thru 1171=3) (1172 thru 1212=1) (1213 thru 1247=2)
  (1248 thru 1370=1) into type/
  subno (1 thru 642=1) (643 thru 1370=2) into form/
  subno (1 thru 358=1) (359 thru 501=2) (502 thru 642=3)
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  subno (1 thru 37=1) (38 thru 78=2) (79 thru 117=3)
  (118 thru 157=4) (158 thru 192=1) (193 thru 237=2)
  (238 thru 276=3) (277 thru 315=4) (316 thru 358=2)
  (359 thru 397=2) (398 thru 431=2) (432 thru 501=2)
  (502 thru 567=2) (568 thru 608=2) (609 thru 642=2)
  (643 thru 689=1) (690 thru 736=2) (737 thru 781=3)
  (782 thru 826=1) (827 thru 859=2) (860 thru 895=3)
  (896 thru 931=4) (932 thru 972=2)
  (973 thru 1022=2) (1023 thru 1060=2) (1061 thru 1112=2)
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sort cases by subno
compute post=2
list
finish
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St Andrews Post Survey

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data list fixed file='andrew.dat' records=1 / subno nstreams c1 to c70
(f4.0,f1.0,1x,70(f1.0))
recode c1 to c70 (missing=3)
compute c71 =30 + c1 - c8 + c15 - c22 + c29 - c36 + c43 - c50 + c57- c64
compute c72 =30 -c2+ c9- c16- c23-c30+c37- c44+ c51- c58+ c65
compute c73 =30 + c3-c10+ c17-c24+ c31- c38+ c45- c52+ c59- c66
compute c74 =30 + c4-c11+ c18-c25+ c32- c39+ c46- c53+ c60-c67
compute c75 =30 + c5- c12+ c19- c26+ c33- c40+ c47- c54+ c61- c68
compute c76 =30 + c6- c13+ c20- c27+ c34- c41+ c48- c55+ c62- c69
compute c77 =30 -c7+ c14- c21+ c28- c35+ c42- c49+ c56- c63+ c70
variable labels c71 'Application of sc. kn.'
/ c72 'understanding of nature of science'
/c73 'Attitude to scientific enquiry' /c74 'Adoption of scientific att'
/c75 'Enjoyment of science lessons' /c76 'Leisure interest in science'
/c77 'Career interest in science'
Recode subno (1 thru 157=1) (158 thru 315=2) (316 thru 358=3)
(359 thru 397=4) (398 thru 431=5) (432 thru 501=6)
(502 thru 567=7) (568 thru 608=8) (609 thru 642=9)
(643 thru 781=1) (782 thru 931=2) (932 thru 972=3)
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subno (1 thru 157=1) (158 thru 315=3) (316 thru 358=2)
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into streams/
subno (1 thru 1247=1) (1248 thru 1370=2) into time
compute post=2
sort cases by subno
list
finish
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02884 12134113145531254111332312352542113332 2212524112532231252432335334241
02932 2324525545252352212154252552225221552255522221154242 5222524252224543
02964 1221215541454125111251245341132122351234411132113432454211432251242441
02972 1332314344534125213231234322135112532134311312123413343113222141234431
03011 114242533544421512325335 5421321124513544221212244554432134322 1455341
03021 1345414341544153125543425354154345154323445153454314545443435345435422
03032 245212535535251 311511115353132121555115321131225521313311232135554312
03042 1523515234553123311142334352233121431235515134123522231241 25313251535
03062 111541554255111111114511135212411125422523221211353 241121322211254541
03084 125351324125321533124312554224122 454123311121212452133215312154521551
03121 2132354444143423214132245245232122342444454422445423242214323223243422

APPENDIX 4.13 Raw Data: New Zealand students

```
Title "Programme segment for reading data"
data list fixed file='andrew.dat' records=4 / c1 to c70 subno class
  (28(f1.0,1x)/21(f1.0,1x)/21(f1.0,1x),f3.0,1x,f2.0/)
compute c71 = c1 - c8 + c15 - c22 + c29 - c36 + c43 - c50 + c57- c64
compute c72 = -c2+ c9- c16- c23-c30+c37- c44+ c51- c58+ c65
compute c73 = c3-c10+ c17-c24+ c31- c38+ c45- c52+ c59- c66
compute c74 = c4-c11+ c18-c25+ c32- c39+ c46- c53+ c60-c67
compute c75 = c5- c12+ c19- c26+ c33- c40+ c47- c54+ c61- c68
compute c76 = c6- c13+ c20- c27+ c34- c41+ c48- c55+ c62- c69
compute c77 = -c7+ c14- c21+ c28- c35+ c42- c49+ c56- c63+ c70
variable labels c71 'Social Implications' / c72 'Normality of Scientists'
/c73 'Attitude to scientific enquiry' /c74 'Adoption of scientific att'
/c75 'Enjoyment of science lessons' /c76 'Leisure interest in science'
/c77 'Career interest in science'
value labels class 2 'interactive class' 1 'traditional class'
list
finish
```

NZ data

```
2 4 3 1 1 1 3 4 2 5 2 5 3 2 2 5 2 1 3 3 3 5 2 3 3 3 2 1
2 2 2 1 1 3 4 4 4 5 5 5 4 3 2 5 1 2 1 3 4
5 2 5 4 5 3 2 2 4 1 2 1 3 5 5 1 5 5 5 4 3 001 1

3 3 2 2 1 1 5 5 3 4 4 5 4 2 1 3 2 2 3 2 4 3 3 3 5 5 4 2
3 3 2 2 2 1 5 4 3 4 4 5 4 2 3 3 2 2 1 1 5
4 3 4 4 5 4 2 3 3 2 2 2 3 5 4 2 4 4 5 4 1 002 1

4 2 2 1 2 2 2 2 2 2 2 4 5 4 4 5 2 2 5 4 2 5 4 4 5 4 2 4
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4 2 4 5 2 5 2 2 4 4 1 4 2 4 4 1 2 5 2 4 4 003 1

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3 4 2 2 5 4 1 4 3 2 4 4 2 5 4 3 2 2 4 4 2
3 2 2 4 3 2 4 3 2 2 2 4 4 4 3 4 4 3 2 4 005 1

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2 3 1 2 2 3 3 4 3 2 4 5 3 5 2 3 2 1 3 3 3
4 2 4 3 4 2 3 4 3 1 2 2 4 4 4 2 4 5 3 3 5 006 1

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4 2 5 5 3 2 2 2 2 1 1 4 2 2 4 1 1 4 3 4 4 007 1

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4 3 2 2 4 4 3 3 3 4 4 4 3 4 4 3 2 2 3 4 4
2 2 4 4 4 2 3 3 4 2 2 3 4 4 2 3 4 4 4 3 4 008 1
```

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4 3 1 2 4 3 3 2 2 5 4 4 2 5 4 3 1 2 4 3 3
2 2 5 3 4 1 3 4 2 1 2 4 3 1 3 2 5 4 3 2 5 017 2

APPENDIX 5.1 : Multivariate analysis of the science-related attitudes scales with the independent factors of schools and Form level.

Effect: The nine schools

Multivariate test of significance (S = 7, M = 0, N = 390)

Test Name	Value	Approx. F	Hypoth. DF	Error DF	Sig. of F
Wilks	.7356	4.4176	56.00	4216.51	<0.01

Univariate F tests with (8, 788) degrees of freedom.

S C A L E (variable application)	Hypoth. Sum of squares	Error Sum of squares	Hypoth. Mean squares	Error Mean squares	F	Signifi- cance of F
1. Application of Scientific Knowledge	1145.77	18923.4	143.22	24.02	5.96	*
2. Understanding the Nature of Sscience	939.10	17167.61	117.39	21.79	5.39	*
3. Attitudes to Inquiry	1979.35	25312.29	247.42	32.12	7.70	*
4. Adoption of Scientific Attitudes	1195.81	18191.25	149.48	23.09	6.47	*
5. Enjoyment of Science Lessons	826.35	23235.11	103.24	29.949	3.50	*
6. Leisure Interests in Science	938.72	25427.15	117.34	32.27	3.63	*
7. Career Interests in Science	1129.17	28008.77	141.15	35.54	3.97	*

Note: * p<0.01

APPENDIX 5.2 : One-way ANOVAS on the nine schools with (8, 796) degrees of freedom.

S C A L E	Sum of Squares	Mean Squares	F	Significance of F
1. Application of Scientific Knowledge	1261.20	157.65	6.12	*
2. Understanding the Nature of Science	916.17	114.52	5.11	*
3. Attitudes to Inquiry	2029.42	253.68	7.46	*
4. Adoption of Scientific Attitudes	1214.45	151.81	6.36	*
5. Enjoyment of Science Lessons	895.53	111.14	3.65	*
6. Leisure Interests in Science	1050.37	131.30	3.94	*
7. Career Interest in Science	1226.57	153.32	4.20	*

Note: * $p < 0.01$

APPENDIX 5.3 : Multivariate analysis of the science-related attitudes scales with the independent factors of Form level, type of school, and gender.

Effect: Form level

Multivariate test of significance (S = 1, m = 2½, N = 395)

Test Name	Value	Approx. F	Hypoth. F	Error DF	Sig. of F
Wilks	.9074	4.55	7.0	792.0	*

Univariate F tests with (1, 798) degrees of freedom.

S C A L E (variable application)	Hypoth. Sum of squares	Error Sum of squares	Hypoth. Mean squares	Error Mean squares	F	Signifi- cance of F
1. Application of Scientific Knowledge	872.36	19698.41	872.36	24.68	35.34	*
2. Understanding the Nature of Science	108.11	18249.40	108.11	22.87	4.73	**
3. Attitudes to Inquiry	946.52	26255.21	946.53	32.90	28.77	*
4. Adoption of Scientific Attitudes	446.71	18866.91	446.71	23.64	18.89	*
5. Enjoyment of Science Lessons	722.71	23864.01	722.71	29.90	24.17	*
6. Leisure Interests in Science	818.39	26091.39	818.39	32.70	25.03	*
7. Career Interests in Science	642.49	28908.53	642.89	36.23	17.23	*

Note: * p<0.01
 ** p<0.05

APPENDIX 5.4 : One-way ANOVAS on mean differences between form level with (1.804) degrees of freedom.

S C A L E	Sum of Squares	Mean Squares	F	Significance of F
1. Application of Scientific Knowledge	957.66	957.66	37.02	*
2. Understanding the Nature of Science	150.14	150.14	6.49	**
3. Attitudes to Inquiry	1276.71	1276.71	36.73	*
4. Adoption of Scientific Attitudes	580.89	580.89	23.73	*
5. Enjoyment of Science Lessons	717.54	717.54	23.42	*
6. Leisure Interests in Science	859.90	859.90	25.88	*
7. Career Interest in Science	617.85	617.85	16.77	*

Note: * $p < 0.01$
 ** $p < 0.05$

APPENDIX 5.5 : Multivariate analysis of the science-related attitudes scales with the independent factors of Form level, type of school, and gender.

Effect: Type of school

Multivariate test of significance (S = 1, m = 2½, N = 395)

Test Name	Value	Approx. F	Hypoth. F	Error DF	Sig. of F
Wilks	.89928	12.67	7.0	792.0	*

Univariate F tests with (1, 798) degrees of freedom.

S C A L E (variable application)	Hypoth. Sum of squares	Error Sum of squares	Hypoth. Mean squares	Error Mean squares	F	Signifi- cance of F
1. Application of Scientific Knowledge	834.70	19698.41	834.70	24.68	33.81	*
2. Understanding the Nature of Science	192.06	18249.40	192.06	22.87	8.40	*
3. Attitudes to Inquiry	1183.55	26255.21	1183.55	32.90	35.97	*
4. Adoption of Scientific Attitudes	733.31	18866.91	733.31	23.64	31.02	*
5. Enjoyment of Science Lessons	190.61	23864.01	190.61	29.90	6.37	**
6. Leisure Interests in Science	327.28	26091.39	327.28	32.70	10.01	*
7. Career Interests in Science	119.32	28908.53	119.32	36.23	3.29	**

Note: * p<0.01
 ** p<0.05

APPENDIX 5.6 : One-way ANOVAS on mean differences between types of schools (single sex and co-educational) with (1, 802) degrees of freedom.

S C A L E	Sum of Squares	Mean Squares	F	Significance of F
1. Application of Scientific Knowledge	941.01	941.01	36.31	*
2. Understanding the Nature of Science	210.08	210.08	9.13	**
3. Attitudes to Inquiry	1297.95	1297.95	37.32	*
4. Adoption of Scientific Attitudes	793.47	793.47	32.70	*
5. Enjoyment of Science Lessons	252.98	252.98	8.20	**
6. Leisure Interests in Science	414.47	414.47	12.34	*
7. Career Interest in Science	170.80	170.80	4.62	**

Note: * $p < 0.01$
 ** $p < 0.05$

APPENDIX 5.7 : One-way ANOVAS on mean differences between types of schools (single sex boys, single sex girls and co-educational schools) with (2, 802) degrees of freedom.

S C A L E	Sum of Squares	Mean Squares	F	Significance of F
1. Application of Scientific Knowledge	949.44	474	18.30	*
2. Understanding the Nature of Science	295.95	147.97	6.43	*
3. Attitudes to Inquiry	1294.89	647.44	18.66	*
4. Adoption of Scientific Attitudes	787.79	393.90	16.25	*
5. Enjoyment of Science Lessons	535.91	267.96	8.68	*
6. Leisure Interests in Science	583.37	291.69	8.67	*
7. Career Interest in Science	529.57	264.78	7.15	*

Note: * $p < 0.01$

APPENDIX 5.8 : Multivariate analysis of the science-related attitudes scales with the independent factors of form level, type of school, and gender.

Effect: Gender

Multivariate test of significance (S=1, m=2½, N=395)

Test Name	Value	Approx. F	Hypoth. F	Error DF	Sig. of F
Wilks	.98196	2.08	7.00	792.00	**

Univariate F tests with (1, 798) degrees of freedom.

S C A L E (variable application)	Hypoth. Sum of squares	Error Sum of squares	Hypoth. Mean squares	Error Mean squares	F	Signifi- cance of F
1. Application of Scientific Knowledge	6.38	19698.41	6.38	24.68	.26	N.S.
2. Understanding the Nature of Science	61.17	18249.40	61.17	22.87	2.67	N.S.
3. Attitudes to Inquiry	.24	26255.21	.24	32.90	.01	N.S.
4. Adoption of scientific Attitudes	.45	18866.91	.45	23.64	.02	N.S.
5. Enjoyment of Science Lessons	278.55	23864.01	278.55	29.90	9.31	*
6. Leisure Interests in Science	164.34	26091.39	164.34	32.70	5.03	**
7. Career Interests in Science	316.85	28908.53	316.85	36.23	8.75	*

Note: * p<0.01
 ** p<0.05
 N.S. p not significant

APPENDIX 5.9 : One-way ANOVAS on Mean Difference for Gender (with school type) with (1, 804) degrees of Freedom

S C A L E	Sum of Squares	Mean Squares	F	Significance of F
1. Application of Scientific Knowledge	854.19	284.73	11.53	*
2. Understanding the Nature of Science	281.81	93.93	4.10	*
3. Attitudes to Inquiry	1143.89	381.30	11.60	*
4. Adoption of Scientific Attitudes	713.31	237.77	10.05	*
5. Enjoyment of Science Lessons	545.43	181.81	6.09	*
6. Leisure Interests in Science	546.88	182.29	5.57	*
7. Career Interest in Science	525.49	175.17	4.83	*

* $p < 0.01$

APPENDIX 5.10 : One-way ANOVAS on mean differences for gender (boys and girls) with (1, 804) degrees of freedom.

S C A L E	Sum of Squares	Mean Squares	F	Significance of F
1. Application of Scientific Knowledge	5.13	5.13	0.20	N.S.
2. Understanding the Nature of Science	74.92	74.92	3.26	N.S.
3. Attitudes to Inquiry	0.11	0.11	0.003	N.S.
4. Adoption of Scientific Attitudes	0.12	0.12	0.005	N.S.
5. Enjoyment of Science Lessons	340.14	340.14	11.03	*
6. Leisure Interests in Science	199.67	199.67	5.95	**
7. Career Interest in Science	366.03	366.03	9.89	*

Note: * $p < 0.01$

** $p < 0.05$

N.S. p not significant

APPENDIX 5.11 : Multivariate analysis of the science-related attitudes scales for interaction effects with factors of Form level, type of school and gender.

Multivariate test of significance (S = 1, m = 2½, N = 395)

Effect	Test Name	Value	Approx. F	Hypoth. F	Error of	Sig. of F
1. Form level by type of school by gender	Wilks	.98471	1.76	7.00	792.00	N.S.
2. Gender by Form level	Wilks	.98591	1.62	7.00	792.00	N.S.
3. Type of school by Form level	Wilks	.98469	1.76	7.00	792.00	N.S.
4. Type of school by gender	Wilks	.99419	.66	7.00	792.00	N.S.

Note: N.S. p not significant

APPENDIX 6.1 : Sample of a case study teacher lesson plan on measurement before the new curriculum

- Form - 1G
- Subject - General Science
- Topic - Conversion from grammes to kilogrammes and from kilogrammes to grammes.
- Time Duration - 80 mins.
- General Aim - By the end of the lesson pupils should be able to convert from one unit of measurement to another.
- Specific Aim - By the end of the unit, pupils should be able to convert from kilogrammes to grammes, milligrammes to grammes.

Introduction -

- (a) Revision of previous lesson by asking questions.
- (b) Teacher introduces topic by writing the "Units of measurement," table on the blackboard.

10 milligrammes (mg)	=	1 centigramme
10 centigrammes (cg)	=	1 decigramme
10 decigrammes (dg)	=	1 gramme
10 grammes (g)	=	1 decagramme
10 decagrammes (dcg)	=	1 hectogramme
10 hectogrammes (hg)	=	1 kilogramme (kg)

- (c) The basic unit of mass is the kilogramme. The original kilogramme (kg) is kept by the International Bureau of Weights and Measures at Sèvres in France.

Convert the following:

1. A body has a mass of 3 kg. What is its weight?
A mass of 1 kg weighs 9.8 N
So a mass of 3 kg weighs
 $9.8 \times 3 \text{ N} = 29.4 \text{ N}$ ans.
2. Some mangoes are placed on a spring balance and found to weigh 4.9 N. What is their mass?
9.8 N is the weight of 1 kg
So 4.9 N is weight of $\frac{4.9}{9.8}$
 $9.8 = 0.8 \text{ kg}$ ans.
3. What force does a man exert on a stone of mass 2.85 kg when he lifts it from the ground?

on a mass of 1 kg a man exerts 9.8 N
on a mass of 2.5 kg he'll exert $9.8 \times 2.5 \text{ N}$

 $= 24.5 \text{ N}$ ans.

4. Convert 3.49 kg to grammes

$$1 \text{ kg} = 1000 \text{ g}$$

$$3.47 \text{ kg} = 1000 \times 3.47 \text{ g} = \underline{3470 \text{ g}} \text{ ans.}$$

5. Convert 0.086 kg to grammes

$$1 \text{ kg} = 1000 \text{ g}$$

$$\begin{aligned} 0.086 \text{ kg} &= 1000 \times 0.086 \text{ g} \\ &= \underline{86 \text{ g}} \text{ ans.} \end{aligned}$$

6. Convert 9500 g to kilogrammes.

$$1000 \text{ g} = 1 \text{ kg}$$

$$1 \text{ g} = \frac{1}{1000} \text{ kg}$$

$$9500 \text{ g} = \frac{9500}{1000} \text{ kg}$$

$$= \underline{9.5 \text{ kg}} \text{ ans.}$$

7. Convert 905g to kilogrammes

$$1000 \text{ g} = 1 \text{ kg}$$

$$1 \text{ g} = \frac{1}{1000} \text{ kg}$$

$$905 \text{ g} = \frac{905}{1000} \text{ kg}$$

$$= \underline{0.905 \text{ kg}} \text{ ans.}$$

APPENDIX 7.1 : Lesson Plans for the Unit on Measurement

LESSON PLAN & NOTE

LESSON 1

Form = 1 - 02,03

Subject: General Science

Class - size = 45 per stream

TOPIC: Measurement

DURATION: 80 minutes

AIM: To involve children in such activities as to clearly bring out the concept of measurement and the importance of accuracy in science.

OBJECTIVES: By the end of the lesson, from activities outlined, the pupils should be able to

- (1) Give a simple definition of the word - measurement.
- (2) Identify quantities we usually measure.
- (3) Identify units of measurement with respective system of measurements.
- (4) Identify instruments used to measure named quantities.
- (5) Use some common, simple instruments (ruler, spring balanced, protractor, watch etc.) correctly.

MAIN IDEA: The core of the lesson is that science as a way of finding out things has a language of describing events or phenomena. Measurement is very important in Science.

MATERIALS: Foot rules, metre rules, internal and external calipers, empty milk tins, oranges, water, measuring cylinder, spring balance, wrist watches.

INTRODUCTION: Teacher starts lesson by asking such questions to arouse children's previous knowledge on measurement from everyday life. For example; (a) Who can tell me something about our topic on the board? (b) When do we measure? (c) How do we measure. (d) What do you understand from that word?

*This takes about five minutes.

DEVELOPMENT

Step 1: Children are arranged in groups. Each group is given each of the instruments to be used.

Step 2: Teacher writes the class exercise on the board.

1. Measure the length and width of your desk.
2. Measure the length and width of the window nearest to you.
3. How much does your mathematical set weigh?
4. How long does it take you to answer the four questions?

Each child should write the findings in his own book.

Step 3: Children are left, guided by teacher, to do the exercises/assignment on their own. Teacher goes round to make sure all students are doing the exercises correctly. This takes about 30 minutes.

Step 4: At the end of the 30 minutes exercise, teacher can write children's findings on the board as general information. This can be done in the form of a table:

Quantity measured	Unit(s) used in Mment.	Instrument(s) used
1. Time		
2. Volume		
3. Weight		
4. Distance		
5. Angles		

CONCLUSION: At this point teacher stresses the importance of knowledge of units of measurement. It should be emphasised that it is an important concept to all, scientists and laymen alike - it is useful in the kitchen, in the garden, in the market, in class, in hospitals, in factories, tailor's shop, stores etc.

ASSESSMENT/EVALUATION: Teacher asks a few questions to check exactly what children have learnt in the lesson. Children are allowed to ask questions and teacher clarifies these points of obstruction and confusion.

Assignment: Teacher may give children work they can do at home and bring for correction later.

LESSON 2

TOPIC: Measurement - International units of measurements.

DURATION: 40 minutes.

AIM: To help students distinguish between local and international units of measurement and be made familiar with the two international units of measurement for length, mass, volume and time.

OBJECTIVES: By the end of the lesson children should be able to

- (1) understand and appreciate the need for standardisation in the units of measurement;
- (2) learn about the main units - metric and the British systems of measurement for length, mass, time and volume;
- (3) learn about the metric units of measurement for length, mass, volume and time.

INTRODUCTION: Though classroom demonstration and explanation, teacher guides the children to understand the major weakness of local units of measures, and appreciate the need for standardisation of units of measurement in science.

DEVELOPMENT: From the previous lesson, teacher guides children to classify the two international systems of measurement - the metric and the British system. Teacher guides the students to make a table of the various metric and British units for measuring length, mass, volume and time by completing the table below.

Quantity measured	Metric	F.P.S.
Length	Metre	Feet
Mass	Kilogram	
Volume	Litre	Cubic feet
Time		

Teacher teaches students about the various subunits of the metric system for measuring length, mass, volume and time. Teacher concludes the lesson by writing on the board the mathematical relationships between the various subunits.

LESSONS 3 and 4

DURATION: 40 minutes each

TOPIC: The correct use of measuring equipment

AIM: To give the children enough exercises and activities that can help them measure very accurately with the instruments provided.

OBJECTIVES: By the end of the lesson, from materials provided and exercises given, children should be able to

- (1) identify names of measuring instruments.
- (2) measure accurately using the instruments given to them.
- (3) use the instruments carefully and correctly.
- (4) express their results using the correct units.

MATERIALS: Foot rules, metre rules, spring balance, simple scales, internal and external calipers, objects to be measured

INTRODUCTION: Teacher revises with children the lessons - by asking questions such as (a) Why do we measure? When do we measure? Teacher also asks children to recall the names of simple instruments used in measurements.

DEVELOPMENT: The children are given exercises (in groups). Teacher writes the following exercises on the board.

Step 1: Distance

- (1) Measure the length of your desk.
- (2) Measure the length of your exercise book.
- (3) Measure the width of your desk.
- (4) Measure the height of your desk.
- (5) Measure the height of your classroom.

Step 2: Weight

Exercise

- (1) Weigh the following using a spring balance or scale.
 1. The mathematical set.
 2. Wooden block.
 3. Stone

Step 3: Time

- (1) How long does it take for a boy to go to the gate?
- (2) How long does it take him to run round the building twice?

Step 4: Volume

Use a measuring cylinder to find

- (1) The volume of a given amount of water.
- (2) The volume of solids - stone, sand.

Teacher goes round to see that every child does the work and guides where each goes wrong. Teacher sees that each answer has a unit.

Teacher then asks pupils to report their results and he writes the answers on the blackboard.

Conclusion: Teacher at this point concludes the lesson by stressing or laying emphasis on the importance of accurate measurement in science.

ASSESSMENT AND EVALUATION

Teacher asks a few questions to round up the lesson. From this certain weak areas which need more explanations may be spotted. Teacher also notes how much work still needs to be done.

LESSON 5

TOPIC: Conversion from one unit to the other

DURATION: 40 minutes.

AIM: To show that a particular distance (or weight of an object) is the same only units of measurement make their figures vary in magnitude.

OBJECTIVE: By the end of the lesson children should, from the outline of exercises and the teacher's explanations, be able to (1) convert from centimetres to metres, (2) convert from metres to kilometres, (3) multiply and divide where such are necessary.

MATERIALS: Exercises on conversion, table to guide children and worked examples.

INTRODUCTION: Teacher repeats history of how the metric system was developed and so named. The metre as the basis and foundation unit from which like mm, cm, m, km were derived. The table is summarised on the B/B and children asked to read.

10 mm = 1 cm, 100 cm = 1 m, 1000 m = 1 km.

DEVELOPMENT: Exercises are given to children after teacher has done two or three examples on the board for all to see.

Teacher goes round in the class and marks the childrens' work. This enables teacher to note the students who are following the lesson. If more lag behind, exercises are done on the board by volunteers or appointees. Two of such exercises may be enough.

Exercises given are this time meant to be done correctly. Teacher and children do the corrections together on the board.

CONCLUSION: The lesson is concluded. Teacher formulates the rules: when we convert from a larger unit to a smaller one - we Multiply, but when we convert from a smaller unit to a larger one we Divide.

In a given problem children should identify the direction of conversion and apply appropriate rule and table.

ASSESSMENT: Teacher asks a few questions - to test what children have learned from the lesson.

LESSON 6

TOPIC: Making models of measuring instruments.

DURATION: 80 minutes.

AIM: To teach students simple skills on how to calibrate simple measuring instruments.

OBJECTIVES: By the end of the lesson, from activities given children should be (1) convinced that they can do something worthwhile, (2) able to calibrate sticks as a metre rule, a foot rule, (3) able to construct a simple scale for measuring weight.

MATERIALS: Long sticks cut by pupils, metre rules, scales, standard weights, tin lids, flat boards, card boards, stones and other objects to be weighed, strings, rubber bands.

INTRODUCTION: Teacher starts by demonstrating to the class how to calibrate or graduate the sticks into rulers which they can use in the absence of the imported or ready-made meter rules.

DEVELOPMENT: Children are left to work in groups. Teacher makes follow up to see that the work is done properly and correctly.

Other children are grouped in threes to calibrate simple balances for measuring weights. A straight stick is used and points are marked on this stick corresponding to added standard weights in a scale pan. Students should then use the calibration on the stick to measure the weight of unknown objects.

Children continue the work on their own while teacher guides and corrects them at points necessarily.

CONCLUSION: Children are commended and praised for good work done.

ASSIGNMENT: Children are asked to take the materials home and finish up or improve on the constructions.

APPENDIX 7.2 : Lesson Plans for the Unit on Force

FORM: 2 CLASS SIZE - approx. 40 per stream

SUBJECT: GENERAL SCIENCE TOPIC - FORCE

L E S S O N 1

DURATION: 40 minutes

AIM. To elicit pupils' understanding of the term Force and examples of kinds of forces they are familiar with.

OBJECTIVES. By the end of the lesson, the pupils should have communicated with the teacher.

- (i) why it is important to study about forces.
- (ii) their understanding of the word Force.
- (iii) examples and meaning of kinds of forces they are familiar with.

INTRODUCTION. Teacher uses everyday applications of the principle to guide the pupils to come up with the word Force.

DEVELOPMENT

- Step 1 Teacher writes Force on the board and asks for pupils' understanding of the word, encouraging every pupil to say something. Teacher writes the pupils' answers on the board.
- Step 2 Teacher asks pupils for examples and meaning of kinds of forces they are familiar with, again encouraging total class participation.
- Step 3 Teacher goes over the answers on the board with the pupils explaining which of the pupils answers are or are not the scientific meaning and examples of Force.

CONCLUSION. Teacher summarises the lesson by stressing the importance of knowledge of Force in everyday life.

L E S S O N 2 and 3

DURATION: 80 minutes each

AIM. To teach students the scientific meaning of Force and examples of common types of forces.

OBJECTIVES. The demonstration and explanation to be carried out during the lesson should enable the pupils to

- (i) learn the scientific meaning of the term Force; and
- (ii) be able to name and describe qualitatively examples of common types of forces.

MATERIALS: Bar magnets, nails, stones, string, clamps, wooden blocks, pulleys, and scale pans.

INTRODUCTION. Teacher revises previous lesson by asking for pupils' understanding of the term Force. Teacher gives brief introduction of the lesson of the day and divide the class into small groups.

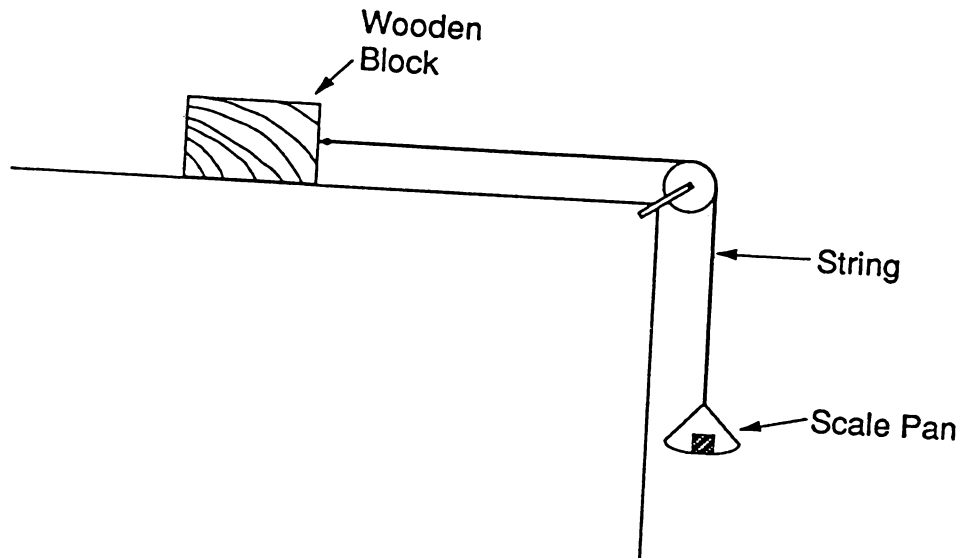
DEVELOPMENT

Step 1 Teacher supplies each group with the materials listed above.

Step 2 Teacher writes the following exercises and instructions on the board.

- (i) Hold a stone in the air. Let it go. Explain what happens and why. Tie a piece of thread round the same stone. Hang it in the air by holding on to the end of the string. What stops the stone from falling? Tie the same thread round a bigger stone. Suspend it in the air and explain what happens.

- (ii) Hold the bar magnet in one hand and slowly move it towards a nail resting on your desk. Explain what you feel and observe.
- (iii) Set up the apparatus as shown below. Add stones one at a time into the scale pan. Does the wooden block move? Why?



- Step 3 Teacher goes round to make sure that every pupil takes part in the exercise and the teacher guides the pupils if necessary.
- Step 4 At the end of the activities, teacher calls for pupils' results, writing each group results on the board and allowing discussions on the results. Teacher summarizes the discussions by listing important outcomes of the activities e.g.

(a) Establish the correct framework of Force -

- (i) Force can produce motion.
- (ii) Force does not necessarily produce motion.
- (iii) Force can change the direction of a moving object.
- (iv) Force can stop a moving object.

- (b) Name and give qualitative descriptions of common types of forces - gravitational, tensional, frictional, magnetic and reactional.

CONCLUSION. Teacher concludes the lesson by summarising the above frameworks to give a simplified scientific definition of the term Force.

ASSESSMENT/EVALUATION. Teacher asks few questions to check if pupils can describe correctly the meaning of Force and examples of some types of forces in their own words. Teacher can give small projects to pupils to identify examples of kinds of forces in common activities like pulling a cart, drawing water from a well, game of tug of war, hanging hammock etc.

L E S S O N 4

DURATION: 40 minutes

AIM. To teach students the uses and effects of some common types of forces.

OBJECTIVES. At the end of the lesson, the pupils should be able to give qualitative explanations of common practices involving principle of Force.

INTRODUCTION. Teacher introduces the lesson by revising the previous lesson to check pupils' understanding on Force and examples of types of forces.

DEVELOPMENT

Step 1 Teacher writes selected problems on the board and asks pupils to write down the answers to these problems in their notebooks. Example of such problems are

- (i) Why is it difficult to walk on a highly polished floor?

- (ii) Why do vehicles slow down when approaching curves?
- (iii) How come aeroplanes or helicopters are able to fly?

Step 2 Teacher asks pupils to discuss their answers in small groups. After allowing some time for the group discussion, the teacher can call on different groups to present their answers. Each group answer is discussed by the whole class and clarified by the teacher.

CONCLUSION. The teacher will round up the lesson by offering qualitative explanations of the uses and effects of some types of forces e.g.

gravitational	- walking
frictional	- walking, wears and tears
reactional	- aeroplanes, motors in fishing boats
centripetal	- planetary motion, dangerous when fast moving vehicles approach bends.
tensional	- hanging hammock, pulleys.

ASSESSMENT/EVALUATION. Teacher asks few questions to check pupils understanding of these explanations. Teacher can ask the pupils to do investigations on their own on examples they find difficult to explain.

APPENDIX 8.1 : Pre- and Post-test Results for Student Attitudes to Science

Results here refer to the reporting in Chapter 8 Section 8.3. The statistical procedures adopted were along the same lines as those used in the large sample survey of student attitudes using the attitudes to science questionnaire.

For the pre- and post- testing the variables were: the effect of time, the effect of class streams and the effect of school. Multi-variate techniques were used to identify any main and interaction effects.

The pre- and post-test data were analysed by comparing the mean scores of Form 2 students who studied the new curriculum with those of Form 2 classes of the 1988/89 school year who had studied the old curriculum. Comparisons between the two categories of students in each of the two schools were made using the factors named above. Results of these analyses are presented in the following sections, starting with effects of the new curriculum on students in individual schools.

[a] Bo School

Effect of Time

Results of analysis of variance showed that the factor time was not significant. This meant that mean score differences between students who studied the new Science for All curriculum, and those who had studied the old curriculum in Bo school were not statistically significant.

Effect of Class Streams

The multivariate tests of significance showed that the factor class streams was significant (Wilks lambda $P \leq 0.05$, see table below).

Multivariate Analysis of Science-related Attitudes with the Independent Factors Time and Class Streams (Bo School)

Effect: <u>Class Streams</u>						
Multivariate Test of Significance (S = 2, M = 2, N = 102)						
Test Name	Value	Approx. F	Hypoth DF	Error DF	Sig. of F	
Wilks	0.86911	1.79	14.00	344.00	**	
S C A L E	Hypoth. Sum of Squares	Error Sum of Squares	Hypoth. Mean Squares	Error Mean Squares	F	Sig. of F
1. Application of Scientific Knowledge	102.46	4947.75	51.23	23.34	2.19	N.S.
2. Understanding the Nature of Science	110.36	4615.27	55.18	21.77	2.53	N.S.
3. Attitudes to Inquiry	186.12	7541.25	93.01	35.57	2.61	N.S.
4. Adoption of Scientific Attitudes	119.97	4297.01	59.98	20.67	2.96	N.S.
5. Enjoyment of Science Lessons	129.75	4373.03	64.88	20.63	3.15	**
6. Leisure Interest in Science	121.63	5894.55	60.82	27.19	2.19	N.S.
7. Career Interest in Science	142.42	7877.32	71.21	37.16	1.92	N.S.

Note ** $p \leq 0.05$
 N.S. p not significant

The ANOVA results for this factor was significant for one subscale only, Enjoyment of Science Lessons ($p \leq 0.05$, see table below). The table shows that the stream 3 students scored significantly higher means than the stream 1 students. But difference in mean scores between streams 3 and 2 students just approached significance.

**Mean score comparisons for the factor class streams
(Bo school, N = 218)**

<u>Enjoyment of Science Lessons Scale</u>	
Streams	Mean Scores
1	20.2
2	20.0
3	22.1

Effect of Time by Class Streams

Multivariate tests of significance indicated that the factor time by class streams was not significant.

[b] St. Andrews School

Effect of Time and ClaSS Streams

Results of the multivariate tests of significance revealed that the factor time was not significant. Thus, differences in mean scores between the Form 2 students who studied the new Science for All curriculum and those who studied the old one were not statistically significant. The multivariate tests showed that the factor class streams was also not significant.

Effect of Time by Class Streams

The multivariate tests of significance revealed that the factor time by class streams was significant (Wilks lambda $P \leq 0.05$, see table below).

Multivariate Analysis of Science-related Attitudes with the Independent Factors Time and Streams (St. Andrews School)

Effect: Time by Class Streams						
Multivariate test of significance (S = 2, M = 2, N = 45)						
Test Name	Value	Approx. F	Hypoth. DF	Error DF	Sig. of F	
Wilks	0.76027	1.93	14.00	184.00	**	
Univariate F-tests with (2, 98) degrees of freedom						
S C A L E	Hypoth. Sum of Squares	Error Sum of Squares	Hypoth. Mean Squares	Error Mean quares	F	Sig. of F
1. Application of Scientific Knowledge	58.62	2539.00	29.31	25.91	1.13	N.S
2. Understanding the Nature of Science	210.95	2588.18	105.47	26.41	3.99	**
3. Attitudes to Inquiry	90.09	3301.96	45.69	33.69	1.34	N.S
4. Adoption of Scientific Attitudes	151.73	2221.79	75.87	22.67	3.35	**
5. Enjoyment of Science Lessons	192.23	2571.74	96.12	26.24	3.66	**
6. Leisure Interest in Science	33.74	2869.01	16.87	29.28	0.58	N.S
7. Career Interest in Science	6.72	3504.64	3.36	35.76	0.09	N.S

N.S. p is not significant

** $p \leq 0.05$

The ANOVAS for this factor were significant for three scales ($P \leq 0.05$). These were: Understanding of the Nature of Science, Adoption of Scientific Attitudes, and Enjoyment of Science Lesson scales. Mean score differences for the two categories of students on these scales are displayed in the table below.

Comparison of Mean Scores Between St. Andrews School Students of the Old and New Curricula for the Factors Time by Streams (N=104).

<u>Understanding the Nature of Science Scale</u>		
Streams	M E A N S C O R E S	
	Old Curriculum	New Curriculum
1	23.8 ¹	25.8 ¹
2	28.9 ²	24.6 ¹
3	25.5 ¹	23.4 ¹
<u>Adoption of Scientific Attitudes Scale</u>		
1	24.5 ¹	22.5 ¹
2	23.0 ¹	26.1 ²
3	27.6 ¹	26.2 ¹
<u>Enjoyment of Science Lessons Scale</u>		
1	24.9 ¹	23.4 ¹
2	21.6 ¹	24.3 ²
3	27.6 ¹	23.5 ¹

Note: Mean scores in the same row carrying different index numbers are significantly different by Student Newman-Keuls ($P \leq 0.05$).

The figures displayed in the table show no regularity in the pattern of changes in mean scores for the two categories of students. For example, on the Understanding of the Nature of Science scale, stream 2 students of the new curriculum scored significantly higher means than the stream 2 students of the old curriculum. But the stream 2 students of the new curriculum scored significantly higher means than the stream 2 students of the old curriculum on the Adoption of Scientific Attitudes scale. Mean score differences between students of the old and new curricula were not significant for any stream for the Enjoyment of Science Lessons scale.

[c] Bo School and St. Andrews School : Comparison of Pre- and
 Post-Test Results

Effect of Time

The multivariate test showed that the factor time was not significant. However, for illustrative purposes only, the pre- and post-test mean scores for the seven science-related attitudes scales are displayed in the table below. The table also contains group mean scores for Form 2 students on these scales obtained from the large sample survey of science attitudes towards science.

The table shows that the pre and post-test mean scores for students in the two schools were within close ranges with values obtained for Form 2 students from the large sample survey.

Comparison of Pre and Post-test Attitudes to Science Mean Scores for Bo and St Andrews Schools

S C A L E	Bo School		St Andrews		Entire Population		Large Sample Survey of Sci. Att. (N=394)
	(N=189) Old curric.	New curric.	(N=52) Old curric.	New curric.	(N=161) Old curric.	New curric.	
1. Applica- tion of Scienti- fic Knowledge	22.1	21.7	23.1	23.3	22.4	22.2	23.0
2. Under- standing the Nature of Science	25.4	25.6	26.5	24.8	25.8	25.3	25.0
3. Attitudes to Inquiry	23.5	23.7	27.1	28.6	24.6	25.3	25.9
4. Adoption of Scien- tific Attitudes	21.4	22.4	24.4	24.9	22.4	23.2	23.2
5. Enjoyment of Science Lessons	20.3	20.6	23.9	23.8	21.5	21.7	22.2
6. Leisure Interest in Science	20.1	19.4	23.6	22.6	21.2	20.4	22.0
7. Career Interest in Science	20.6	21.4	24.9	24.3	22.0	22.3	22.6

Effect of School

The MANOVA for all seven subscales in the questionnaire taken together showed that the factor school was significant (Wilks lambda $P \leq 0.01$, see table below).

Multivariate Analysis of Science-related Attitudes with the Independent Factors Time and Streams (Bo School and St. Andrews School)

<u>Effect:</u> <u>School</u>						
Multivariate test of significance (S = 1, M = ½, N = 15)						
Test Name	Value	Approx. F	Hypoth. DF	Error DF	Sig. of F	
Wilks	0.8102	10.17	7.00	304.00	*	
S C A L E	Hypoth. Sum of Squares	Error Sum of Squares	Hypoth. Mean Squares	Error Mean Squares	F	Sig. of F
1. Application of scientific knowledge	114.57	7486.76	114.57	24.15	4.74	**
2. Understanding the nature of science	12.76	7203.45	12.76	23.23	0.55	N.S.
3. Attitudes to inquiry	1115.11	10843.21	1115.11	34.98	31.88	*
4. Adoption of scientific attitudes	541.22	6518.81	541.22	21.03	25.74	*
5. Enjoyment of science lessons	726.94	69441.78	726.94	22.40	32.45	*
6. Leisure interest in science	660.57	8763.56	650.57	28.27	23.27	*
7. Career interest in science	740.50	11381.95	740.50	36.72	20.17	*

N.S. p not significant

* $p \leq 0.01$

The corresponding ANOVAS revealed significant differences for six of the seven science-related subscales ($P \leq 0.05$). The post test mean score differences between the two schools on the seven subscales are contained in table below.

Post Mean Score Difference Between Bo and St. Andrews Schools

S C A L E	M E A N S	
	Bo School (N=218)	St. Andrews School (N=104)
1. Application of Scientific knowledge Knowledge	21.9 ¹	23.2 ²
2. Understanding the Nature of Science	25.6 ¹	25.6 ¹
3. Attitudes to Inquiry	23.6 ¹	27.9 ²
4. Adoption of Scientific Attitudes	21.9 ¹	24.6 ²
5. Enjoyment of Science Lessons	20.5 ¹	23.9 ²
6. Leisure Interest in Science	19.7 ¹	23.1 ²
7. Career Interest in Science	21.0 ¹	24.6 ²

Note: Means scores carrying different index numbers are significantly different by Student Newman-Keuls ($p \leq 0.01$)

The table shows that students at the St. Andrews school scored significantly higher means in the post test than students at Bo school on all except for the Understanding of the Nature of Science scale. This trend was similar to what was observed in the large survey of science attitudes towards science. In that survey, group mean scores for students at the St. Andrews school were significantly different from those of Bo school students on all except for the Understanding of the Nature of Science scale.

Interaction Effects Between Factors

Multivariate tests of significance for all seven subscales taken together for the two schools revealed no two way interactions between the factors school by class streams and school by time. However, the MANOVA showed that the factor school by time by class streams was significant (Wilks lambda $P \leq 0.05$, see table below).

**Multivariate Analysis of Science-related Attitudes with the
Independent Factors School, Time and Streams
(Bo School and St. Andrews School)**

Effect: School by Time by Class Stream

Multivariate Tests of Significance (S = 2, M = 2, N = 151)

Test Name	Value	Approx. F	Hypoth. DF	Error DF	Sig. of F
Wilks	0.91832	1.89	14.00	608.00	**

Univariate F tests with (2, 310) degrees of freedom

S C A L E	Hypoth. Sum of Squares	Error Sum of Squares	Hypoth. Mean Squares	Error Mean quares	F	Sig. of F
1. Application of scientific knowledge	230.55	7486.76	115.27	24.15	4.77	*
2. Understanding the nature of science	90.44	7203.45	45.21	23.24	1.95	N.S
3. Attitudes to inquiry	15.59	10843.21	7.11	34.98	0.22	N.S
4. Adoption of scientific attitudes	164.21	6518.80	82.10	21.03	3.90	**
5. Enjoyment of science lessons	244.31	6944.78	122.15	22.40	5.45	*
6. Leisure interest in science	80.34	8763.56	40.17	28.27	1.42	N.S
7. Career interest in science	30.15	11381.95	15.07	36.72	0.41	N.S

N.S p is not significant

* $p \leq 0.01$

** $p < 0.05$

The ANOVA results for this factor indicated significant differences for three of the seven subscales ($P \leq 0.05$). The three scales were: Application of Scientific Knowledge, Attitudes to Inquiry, and Enjoyment of Science Lessons. The mean score differences between these factors for these scales are contained in the following table.

Comparison of Mean Scores on Scales for Which the Factors School by Stream were Significant.

<u>Application of Scientific Knowledge Scale</u>		
M E A N S C O R E S		
	Old Curriculum	New Curriculum
<u>Bo School</u>		
Streams 1	20.9 ¹	21.3 ¹
2	23.6 ²	20.9 ¹
3	21.4 ¹	24.4 ¹
<u>St. Andrews</u>		
Streams 1	23.7 ¹	23.9 ¹
2	21.8 ¹	23.1 ¹
3	25.5 ¹	22.8 ¹
<u>Adoption of Scientific Attitudes Scale</u>		
<u>Bo School</u>		
Streams 1	20.5 ¹	21.6 ¹
2	22.4 ¹	22.6 ¹
3	21.4 ¹	23.7 ²
<u>St. Andrews</u>		
Streams 1	24.5 ¹	22.5 ¹
2	23.0 ¹	26.1 ²
3	27.6 ¹	26.2 ¹
<u>Enjoyment of Science Lessons</u>		
<u>Bo School</u>		
Streams 1	19.7 ¹	20.6 ¹
2	20.5 ¹	19.6 ¹
3	21.3 ¹	22.9 ¹
<u>St. Andrews</u>		
Streams 1	24.9 ¹	23.4 ¹
2	21.6 ¹	24.3 ¹
3	27.61	23.5 ¹

Note: Mean scores carrying different index numbers in the same row are significantly different by ANOVA of simple main effects ($P \leq 0.01$).

The figures contained in the table once more revealed no systematic pattern of change in mean scores either between streams or schools on the three subscales. For example, whereas the Bo school stream 2 students of the old curriculum scored significantly higher means than their counterparts of the old curriculum on the Application of Scientific Knowledge scale, it was the stream 2 and 3 students of the new curriculum from the two schools who scored significantly higher means on the Adoption of Scientific Attitudes scale.

Once again, differences between streams on the Enjoyment of Science Lessons scales just approached significance.

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